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Use of Nickel Slag Waste As Coarse Aggregate In Concrete

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Keywords

Coarse Aggregate; Nickel Slag; Compressive Strength; Normal Concrete.

Abstract

Indonesia is the largest nickel producer in the world. but from another aspect, the problem of ex-mining pits, combustion ash waste, nickel slag and others are environmental issues in the nickel mining industry (nikel.co.id, 2020). Currently, the Ministry of Industry through the research and development unit is trying to raise the potential of nickel slag or slag so that it can be used as industrial raw material that is in line with environmental management in the context of a sustainable economic program (antaranews.com, 2020). Based of this study was conducted on the use of nickel slag as a substitute for coarse aggregate in concrete. This research is an experimental study with the objectives of analyzing the physical and mechanical characteristics of nickel slag, analyzing the compressive strength of concrete using nickel slag as a substitute for coarse aggregate, and analyzing the optimal percentage of nickel slag used as a substitute for coarse aggregate. The results of this study indicate that the use of nickel slag as a substitute for coarse aggregate for 20 MPa concrete, and unable to achieve the planned average compressive strength of 20 MPa plus a margin of 12 MPa, resulted in a decrease in compressive strength and did not provide quality improvement. concrete. The application of nickel slag as a substitute for coarse aggregate in structural concrete with a design compressive strength ≥ 20 MPa is not recommended..

1. INTRODUCTION

Indonesia is the largest nickel producer in the world, but from another aspect, the problem of ex-mining pits, combustion ash waste, nickel slag and others is an environmental issue in the nickel mining industry (nikel.co.id, 2020). Currently, the Ministry of Industry through the research and development unit is trying to raise the potential of nickel slag or slag so that it can be used as industrial raw material that is in line with environmental management in the context of a sustainable economic program (antaranews.com, 2020).

In Southeast Sulawesi, there are several nickel smelters that produce nickel slag waste, including PT. Aneka Tambang in Pomala, Kolaka Regency, and PT. Virtue Dragon Nickel Industry (VDNI) in Morosi, Konawe District (Siti Harlina-detikFinance, 2019). Each mining industry company has a different age and technology in the calcination and reduction process in a reduction furnace to form matte and slag (analisis.id, 2020). so that differences in the shape and gradation of the slag produced also have the potential to occur.

Research on the use of slag as a partial replacement for coarse aggregates caused the bending strength of concrete to decrease and obtained normal concrete specific gravity at a variation of slag replacement of 80%, (Susilowati, Saputro, & Nurhidayati, 2013). Meanwhile, according to Ganti A. (2008) that, the use of low nickel slag as a substitute for coarse aggregates, can increase compressive strength by 12.32% and reduce abrasion by 24.17% and reduce shrinkage by 11.6% compared to normal concrete. Potential utilization of nickel slag (nickel slag) as aggregate up to 100% in concrete (Wijaya & Astutiningsih, 2021)

Several previous studies have been carried out such as (Jalali, Halim, & Salim, 2017), conducting research on the use of concrete paving blocks with variations of 0%, 25%, 75%, and 100%, where the average measurement results of paving blocks show that most of the test objects meet the requirements, especially the composition of a mixture of 1: 3 at all slag levels, compositions of 1: 4 and 1: 5 at slag levels of 0 and 25%; while the rest do not meet because they exceed the required size. The results of the compressive strength test

show that the higher the nickel slag content, the higher the compressive strength of the paving block, and the highest compressive strength is produced by the composition of the mixture of 1:3. Research on nickel slag as a concrete aggregate conducted by (Mustika, Salain, & Sudarsana, 2016), with the composition of cement, sand and gravel set at 1: 2: 3 in units of weight and the magnitude of the cement water factor which is also set at 0.5.

Another research by (Aprianto & Triastianti, 2018), namely the utilization of nickel slag solid waste, rice husks and fly ash into paving blocks, where in this study the use of slag was at most 45%. Characteristics of high-strength concrete with the substitution of steel slag and nickel slag as coarse aggregate (Suwindu, Parung, & Sandy, 2020). The effect of using nickel slag on the compressive strength and flexural strength of geopolymer concrete (Kaselle & Allo, 2021). Comparison of slag substitution in cement and sand in K-225 quality concrete mixture at PT IMIP Morowali Regency (Zainul, Djamaluddin, & Anwar, 2018). The design of non-sand concrete uses nickel vinyl aggregate slag type III (Taufiq, 2019). Effect of high temperature on the compressive strength of concrete using nickel slag as coarse aggregate (Hartono, Aswad, Mursidi, & Nurbaity, 2021). Experimental study of normal quality concrete with coconut shell aggregates and nickel slag (Aprilia, Phengkarsa, & Kusuma, 2021). In addition, the utilization of iron slag waste as a partial replacement material for sand in concrete production (Hijriah & Yunianti, 2021).

Based on the above, as well as to maximize the use of nickel slag waste, in addition to the location of the source material used is different, in this study there will also be a different composition formulation based on the specific gravity and weight of the aggregate content, as well as different variations in nickel slag substitution up to 100%, then in this study, it will be carried out with the title of the use of nickel slag waste as a coarse aggregate in concrete.

1.1 METHOD

1.2 Types of Research

The type of research carried out is experimental research, where the condition is made and regulated by the researcher by referring to the regulations of the Indonesian National Standard (SNI) and related literature. The type of test to be carried out is concrete aggregate testing, normal concrete compressive strength testing substituted for nickel slag material with variations of 0%, 10%, 25%, and 50% to 100%. The proportion of the concrete mixture is made concerning the guidelines of SNI 2834 of 2000. The number of specimens was made of 3 pieces for each of the compressive strength tests at concrete life of 1, 3, 7, 14, and 28 days.

1.3 Research Time And Location

This research was carried out in September 2020 and will end in June 2022 at the Materials and Concrete Laboratory of the Faculty of Engineering, Haluoleo University with material sources located at PT. Virtue Dragon Nickel Industry (VDNI) in Morosi, Konawe Regency, Southeast Sulawesi Province.

1.4 Stages of Research

The procedures and stages of research carried out include; observation and sampling of concrete constituent materials, testing of concrete constituent materials, mix design, making concrete specimens, pressing tests of concrete specimens, and data analysis.

From the observation of material sources, coarse aggregates in the form of nickel slag were obtained from PT. Virtue Dragon Nickel Industry (VDNI) in Morosi, Konawe County. Meanwhile, gravel is obtained from stone crushers produced by PT. Agung Beton Kendari. The river sand was obtained from the Pohara River of Konawe County.

The concrete constituent material tests carried out are tests of the characteristics of coarse aggregates (gravel and nickel slag), and the characteristics of fine aggregates (river sand) with feasibility conditions as shown in table 1 below:

Table 1. Types of testing of aggregate characteristics and specifications required.

No.	Characteristics of coarse aggregates	Specifications	Characteristics of fine aggregates	Specifications
1	Sludge content	Max 5 %	Sludge content	Max 5 %
2	Wear	< 40%	Organic content	< no. 3
3	Moisture content	0,5% - 2%	Moisture content	2% - 5%
4	Volume weight		Volume weight	
	a. Loose condition	1.4-1.9 kg/ltr	a. Loose condition	1.4-1.9 kg/ltr
	b. Solid conditions	1.4-1.9 kg/ltr	b. Solid conditions	1.4-1.9 kg/ltr
5	Absorption	Max 2%	Absorption	Max 2%
6	Specific gravity:		Specific gravity	
	a. Bulk	1.6 - 3.3	a. Bulk	1.6 - 3.3
	b. SSD	1.6 - 3.3	b. SSD	1.6 - 3.3
	c. Apparent	1.6 - 3.3	c. Apparent	1.6 - 3.3
7	Fine modulus	5.50-8.50	Fine modulus	2.50-3.20

(Source: SII 0052-1980)

Mix design of concrete is carried out by referring to the guidelines of SNI 2834 of 2000 concerning procedures for making a normal concrete mixture plan. The targeted average plan compressive strength of 30.48 MPa, was obtained using equation (1). In equation (1) $f'cr$ is the average plan of compressive strength, $f'c$ is the required compressive strength, which is 19.3 MPa, K is the multiplier factor coefficient, which is 1.64 and S is the standard deviation, which is 7 MPa. Variations of concrete mixtures with nickel slag substitutions are complete in table 2.

$$f'cr = f'c + K.\mathrm{S} \tag{1}$$

In equation (2), $f'c$ is the compressive strength with the unit *MPa* which is an indicator of the quality of concrete. *P* is the maximum load of the compressive test equipment with Newton units *(N)* and *A* of the cross-section of the concrete test piece specimen by unit *(mm²)*.

$$f'c = \frac{P}{A} \tag{2}$$

Compressive testing of concrete specimens was carried out at the age of 1 day, 3 days, 7 days, 14 days, and 28 days with variations in nickel slag substitution of 0%, 10%, 25%, 50,% and 100%. Given the need to know the model of the trend of increasing the strength of concrete from the age of 1 day to the age of 28 days in concrete specimens with this slag aggregate, while the limited capacity of the concrete mixer is only 0.3 m³ into to avoid the inhomogeneous of the mixture in each variation, as well as the magnitude of the deviation of compressive strength, the number of samples of concrete cylinder specimens is onlaremade 3 pieces for each age and variation of the mixture. The full testing and variation of concrete mixtures can be seen in table 2 below.

Table 2. Variation of the mixture and testing life of concrete

Variations of Concrete Mix	Types of Testing	Number of Test Objects and Concrete Life				
		1 Day	3 Days	7 Days	14 Days	28 Days
Concrete 0% Slag	Compressive strength	3	3	3	3	3
Concrete 10% Slag	Compressive strength	3	3	3	3	3
Concrete 25% Slag	Compressive strength	3	3	3	3	3
Concrete 50% Slag	Compressive strength	3	3	3	3	3
Concrete 100% Slag	Compressive strength	3	3	3	3	3

(Source: Research Plan 2020).

At the data analysis stage, an analysis of the test results of the characteristics of coarse aggregates (crushed stone and nickel slag), compressive strength and composition of the concrete mixture was carried out. Then analyze the correlation between the characteristics of the coarse aggregate and the resulting compressive strength of the concrete.

2. DISCUSSION

Figure 1. Concrete material under study *(Source: Observations, 2020).*

The results of the Pohara fine aggregate (river sand) test were processed data on the physical condition of the sand, among others; Sludge content is 4.00%, organic content is in category number 2, water content is 3.80%, loose volume weight is 1,401 kg/liter and solid volume weight is 1,525 kg/liter. water absorption 1.781%, bulk specific gravity 2.58 kg/liter, dry specific gravity 2.46 kg/liter and surface dry specific gravity 2.51 kg/liter, and sand smoothness modulus 2.99.

The test results of coarse aggregates (crushed stone) processed data on the physical condition of the sand, among others; sludge content of 1.45%, Wear 33.14%, moisture content of 1.69%, loose volume weight of 1.66 kg/liter and solid volume weight 1.83 kg/liter, water absorption 2.84%, bulk specific gravity (real) 2.75 kg/liter, dry specific gravity 2.55 kg/liter and surface dry specific gravity 2.62 kg/liter and smoothness modulus which is 9.18. Meanwhile, from the test results of nickel slag as a substitute for coarse aggregates, the following characteristic data were obtained: slag sludge content of 0.47%, slag hardness of 2.40%, average volume weight of 1.73 kg/liter, water absorption of 0.91%, surface dry specific gravity of 2.95 kg / ltr, bulk specific gravity 3.01 kg/liter and apparent specific gravity of 2.93 kg/liter, and slag fineness modulus 7.02.

From the results of compressive testing on concrete with normal materials (crushed stone aggregates) and concrete using nickel slag as a substitute for partially or completely broken stone, an average compressive strength was obtained at a variation of 0% nickel slag aged 28 days of 30.77 MPa with a standard deviation of 1.16, at a variation of 10% nickel slag average compressive strength of 30.26 MPa with a deviation of 0.62, compressive strength of 30.1 MPa at a variation of 25% nickel slag with a deviation of 0.3, compressive strength of 30.13 at a variation of 50% nickel slag with a deviation of 0.68 and a compressive strength of 30.38 MPa, and a variation of 100% nickel slag with a deviation of 0.15.

Based on the strength of the 28-day lifespan, concrete without nickel slag obtained a compressive strength of 30.77 MPa, concrete with substitution of 10% nickel slag of 30.26 MPa, concrete with substitution of 25% nickel slag of 30.10 MPa, concrete with substitution of 50% nickel slag of 30.13 MPa and in concrete with 100% nickel slag compressive strength of 30.38. Concrete compressive strength data from each of the other slag substitution variations as in table 3 below:

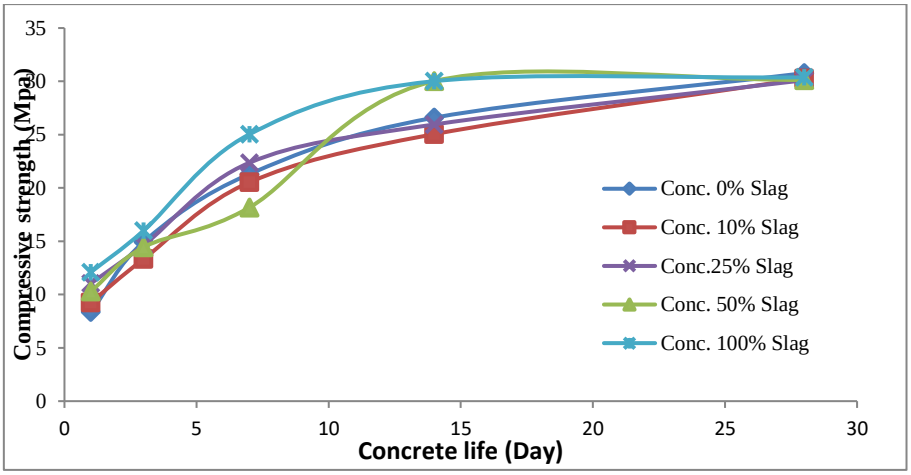
Table 3. Compressive strength of concrete with nickel slag substitution

Variant	Sample	Crushed load (kN) / Compressive strength (Mpa)									
		1 Day		**3 Days**		**7 Days**		**14 Days**		**28 Days**	
	1	145.6	8.2	268.8	15.2	376.4	21.3	469.6	26.6	532.6	30
Concrete 0% Slag	2	150.4	8.5	258.0	14.6	383.8	21.7	455	25.7	572.3	32.4
	3	148.0	8.4	265.5	15.0	370.6	20.9	485.4	27.5	529.5	29.9
Average			***8.37***		***14.94***		***21.30***		***26.59***		***30.77***
	1	178.9	10.1	171.7	9.7	325.0	18.4	348.8	19.7	520.5	29.47
Concrete 10% Slag	2	145.2	8.2	269.2	15.2	394.2	22.3	493.0	27.9	565.0	30.99

Variant	Sample	Crushed load (kN) / Compressive strength (Mpa)									
		1 Day		**3 Days**		**7 Days**		**14 Days**		**28 Days**	
	3	166.5	9.4	265.8	15.0	368.6	20.9	485.5	27.5	535.5	30.32
Average			***9.26***		***13.34***		***20.53***		***25.05***		***30.26***
	1	220	12.46	243.8	13.8	404.2	22.9	535.5	30.3	526.0	29.78
Concrete 25% slag	2	167.2	9.47	277	15.7	395.0	22.4	400.8	22.7	538.6	30.49
	3	198	11.21	254.4	14.4	385.8	21.8	439.0	24.9	530.5	30.04
Average			***11.04***		***14.63***		***22.36***		***25.96***		***30.10***
	1	235.4	13.33	266.80	15.11	293.40	16.61	488.50	27.66	560.20	30.72
Concrete 50% Slag	2	165.4	9.36	229.80	13.01	294.20	16.66	505.50	28.62	515.40	29.18
	3	145.2	8.22	269.20	15.24	375.10	21.24	597.00	33.80	538.50	30.49
Average			***10.30***		***14.45***		***18.17***		***30.03***		***30.13***
	1	197.30	11.17	245.60	13.91	476.00	26.95	590.50	33.41	540.20	30.59
Concrete 100% Slag	2	232.20	13.15	320.20	18.13	428.00	24.23	520.00	29.44	535.00	30.29
	3	211.85	11.99	282.00	15.97	422.40	23.92	480.50	27.21	552.20	30.26
Average			***12.10***		***16.00***		***25.03***		***30.02***		***30.38***

(Source: Observations, 2020).

The previous table shows that normal concrete (without the addition of slag instead of crushed stone) can achieve the planned compressive strength of concrete which is 30.48 MPa of which the compressive strength is obtained by 30.77 MPa. However, in the variation of nickel slag substitution, 5%, up to 100%, only the highest compressive strength of 30.38 MPa was obtained.



Gambar 3. Grafik Peningkatan Kuat Tekan Beton Slag Nikel*(Sumber: Hasil Analisa, 2020)*

The graph of the increase in compressive strength of each concrete life shows that there is an increase in compressive strength in the use of nickel slag instead of crushed stone. In the variation of 50% and 100% nickel slag aged 1 day to 14 days, there is a tendency to increase the compressive strength significantly, the maximum strength is achieved faster but stagnant at the compressive strength below the compressive strength of the plan.

The characteristics of the river sand used qualify as fine aggregates on concrete. The sludge content of 4.04% which is almost close to the limit is 5%, is linear with a large amount of feldspar content of 77% where the compound consists of the elements sodium (Na), Potassium (K) Aluminum (Al) and silicon (Si). The elements sodium and potassium, are reactive alkali metals that are soft, light and easily react with water, resulting in a greater difference in the weight of sand before washing after washing. While aluminum (Al) is a type of heavy metal with a density of 2.70 grams/cm^3, and silicon ica which is a non-metallic element (metalloid) with a mass of 2.57 grams/cm^3 found in dust and sand. Elements of aluminum and silicon oxidized with oxygen will have the potential to increase the level of sludge in the sand. The density of the elements that

make up the chemical compounds in river sand particles will determine the specific gravity, volume weight, and absorption power of the sand.

In portland cement, it consists of 71.59% lime minerals, 20.42% clay, 0.91% iron sand, and 7.07% coal with compound content SiO_2, Al_2O_3, Fe_2O_3, Ca,O, and MgO on each of these minerals (Botahala & Pasae, 2020). In the concrete hydration process, the presence of silicate and aluminate compounds with the specified concentration is found in cement, the hydration reaction occurs for 1-3 hours (cement paste is still plastic or workable condition). Tricalcium aluminate C_3A, then tricalcium silicate C_3S resulting in setting time or hardening to be fast due to the hot temperature, while gypsum ($CaSO_42H_2O$) slows down the time setting process. So that the high content of sludge results in an excess concentration of aluminate in cement paste and mortar, thereby reducing the binding power of cement paste to coarse aggregates.

Overall the characteristics of nickel slag are better than that of crushed stone, except for the weight of the volume. The low volume weight and high percent crushed (5 mm filter pass) on crushed stone due to the impact load of the steel ball of the Los Angles tool, are caused by the presence of cavities in the grains and the level of smoothness of nickel slag 9.8 is higher than the smoothness of crushed stone grains which is only 7.02. While the specific gravity and absorption of nickel slag are better than crushed stone, it is closely related to the content of chemical elements contained in nickel slag and crushed stone. Nickel slag which is 78% dominated by the content of elements magnesium, ferrite, and silicon, Mg 1.80 Fe 0.20 SiO 4 which are transition metals and alkali metals with density Fe 7.86 grams/cm³ and Mg 1.74 grams/cm³, while crushed stone which is 70% dominant contains basalt, sodium (anorthite, sodian, syn) Na 0.45 Ca 0.55 Al 1.55 Si 2.45 O8, with a lighter density, resulting in a higher density or specific gravity of nickel slag than that of crushed stone. The specific gravity of the slag is higher, making the water absorption of the nickel slag lower, while the low specific gravity of crushed stone results in high water absorption. Although in nickel slag some pores or cavities allow it to absorb water, nickel slag which is resulting from high-temperature combustion, the lack of oxygen in the granules, and the surface of the slag grain becomes more waterproof.

From the characteristics of nickel slag above, it is indicated that it contributes to the low compressive strength, this is in line with research (Rahmawati & Suhendro, 2017), which suggests that the wear of linear aggregates against the compressive strength obtained. In addition, the shape of nickel slag grains that tend to be round also results in a lower compressive strength obtained, this is strengthened by research (Masril, 2020), which found that the compressive strength of concrete using crushed stone is higher than the compressive strength with natural gravel as a coarse aggregate, which is 264.237 kg/cm² compared to 246.91 kg/cm².

The correlation and effect of nickel slag substitution on compressive strength can be seen in the correlation analysis and linear regression in the following table.

Table 4. Correlation and effect of nickel slag on compressive strength

Nickel Slag Variations (%) Variable X	Compressive Strength (Mpa) Variable Y
0	30.77
10	30.26
25	30.10
50	30.13
100	30.38
R	-0.258
R^2	0.067

(Source: Analysis results, 2020)

From the correlation analysis, an R-value of 0.25 was obtained, which means that the substitution of nickel slag with the resulting compressive strength of the concrete, has a strong relationship. Meanwhile, from the results of linear regression analysis on the substitution of nickel slag against the compressive strength, a value

of R^2 0.067 was obtained. A graph of the linearity between the variations of nickel slag against compressive strength can be seen in the following chart.

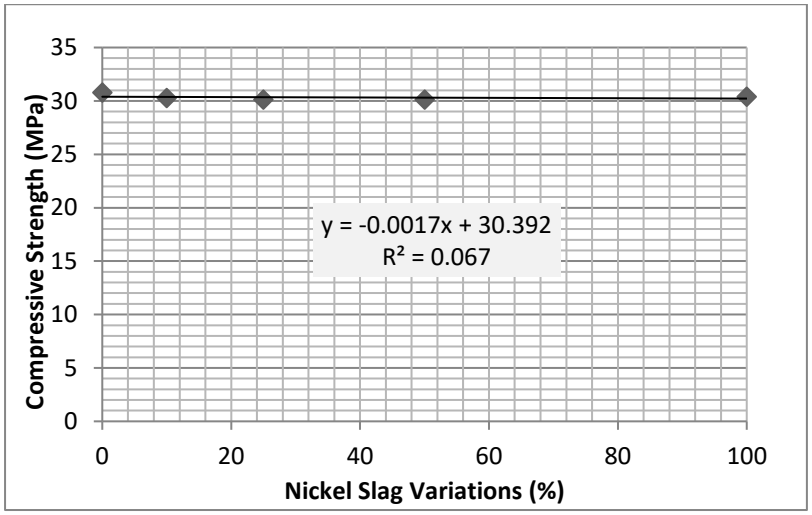


Figure 4. Linear regression model correlation of nickel slag substitution to the compressive strength of concrete

The graph above shows that the substitution of nickel slag does not affect compressive strength. The absence of the effect of replacing crushed stone with nickel slag as a coarse aggregate, either partially or completely does not provide an improvement to the compressive strength of the concrete produced.

3. CONCLUSIONS

The results of this study showed that the use of nickel slag as a substitute for coarse aggregates for 20 MPa quality concrete was not able to achieve the planned average compressive strength of 20 MPa plus a margin of 12 MPa. The use of nickel slag as a substitute for coarse aggregates results in low compressive strength obtained. The low correlation of nickel slag substitution in coarse aggregates to concrete compressive strength indicates the lack of improvement in concrete quality due to the experiment. Thus the use of nickel slag instead of coarse aggregate on structural concrete with a plan compressive strength of ≥ 20 MPa is not recommended for use.

4. ACKNOWLEDGMENTS

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Augmented Reality for Solar System Learning

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Abstract

Along with the rapid development of smartphones and the absence of Solar System learning media in the case study of SMPN 3 RAMPI, for this reason, research, and development of Augmented Reality (AR) for Solar System Learning were made to make Android-based smartphones a media for learning the Solar System using Augmented Reality Technology and introducing Augmented Reality technology to students. The research method is the Research and Development (R&D) method with the ADDIE (analysis, Design, Development, Implementation, evaluation) development model. The results of this study are: (1) This learning application is made using Blender software, Unity, and the Vuforia database, which helps facilitate the development process; (2) This learning application can already be applied in research locations and used as learning media that are more effective, efficient, and interactive so that they can help increase students' interest in learning; (3) The results of the application feasibility test questionnaire with usability-based questions distributed to selected respondents get a score of 90%, which is converted according to the feasibility percentage table, then the application is declared very worthy.

1. INTRODUCTION

Augmented Reality is a technique that combines two-dimensional and three-dimensional virtual objects into a real three-dimensional sphere and then projects these virtual objects in real-time. With the help of tools such as smartphones or tablets with Android and iOS systems with the use of 3D world camera features designed with computer devices, it can be displayed as a popup object (Pamoedji and Maryuni, 2017).

Augmented Reality (AR) is a combination of virtual objects with natural objects. AR can be published for all senses, like hearing, touch and smell. Besides being applied in fields such as health, military, and manufacturing, augmented reality has also been applied in devices that many people use, such as smartphones, by taking advantage of the camera features available in almost all smartphones today. The primary purpose of augmented reality is to create a new environment by combining the interactivity of real and virtual environments in real time so that users feel that the environment created is natural (Susanna Dwi Yulianti Kusuma, 2018). Because of this concept, AR is considered suitable if used as one of the learning media, especially in the material of the solar system.

Learning the solar system is found in science lessons (Natural Sciences) which is a material that elementary school students must know, based on the core competencies of science subjects for SD/MI Class VI Curriculum 2013, that teachers must be able to explain the solar system and the characteristics of members Solar System (Permendikbud, 2018). Natural Science (IPA) is necessary for grade 6 elementary school students, especially in introducing the Solar System. In learning about the solar system, students are invited to get to know the planets, which indirectly invites students to imagine what the conditions are like in the Solar System or look through pictures (Sartika, Y., 2016). However, after knowing the importance of solar system material for students, it turns out that the current learning media for Solar System material is still very minimal, as well as the lack of student response because the teacher has difficulty in explaining the Solar System material (Tresnawati, 2017). In the current system, incredibly remote areas that the internet network has not reached, students only know what the solar system is from textbooks obtained from schools.

Books used in learning the solar system, of course, display pictures of objects from members of the solar system, but to get to know the solar system, it would be better to use props such as planets, the sun and other

objects as a supporting tool so that they can better absorb lessons solar system (Toufan Diansyah Tambunan, 2016).

In line with that, the Global Education Census concluded that Indonesian students are the world's most significant users of technology. Data shows that more than 67% of Indonesian students use smartphones to learn, and 81% more often do homework using smartphones (Global Education Census Report, 2018). Although the use of smartphone is very much in students' activity, the use of AR mobile applications as learning tools is not widespread among teachers (J. Mota et al., 2018).

AR technology can be applied as a learning medium for introducing the solar system to help users get information about the solar system more excitingly by using technology. As it is known that the interest in reading books in Indonesian children is shallow, only 0.01% or around 10,000 people, with the help of technology is expected to increase the number of book readers, especially children. Mobile device technology has become part of the life of modern society. Both young and old cannot be separated from their smartphones (Erlan Darmawan, 2018).

The use of AR technology in the field of education is certainly one example of the entry of the world of education in the 4.0 era where Education 4.0 is a phenomenon that responds to the needs of the fourth industrial revolution, where humans and machines are aligned to find solutions, solve problems and, of course, find innovation possibilities. Primary education to higher education, adapting the educational curriculum to the challenges and needs of the current era. A curriculum allows millennials to gain knowledge and training to become competitive and productive workers (Herman et al. l, 2016).

In the world of education, the development of information technology began to be felt to have a positive impact because the development of information technology and the world of education began to show significant changes (Ismail A at all, 2019). This is important because A good learning process must include interaction, fun, challenge, and motivation and provide space more for students to increase creativity and independence according to their talents and interests of students (Mustaqim I, 2017). But although the world of education has developed very well from time to time, this progress is not supported by the progress of Human Resources (HR) that can be aligned with each other (Fitriah D, 2019).

HR like this is also found in SMP 3 Rampi as a school located in a remote area that does not yet have an internet connection. However, even though it is a remote area, most of the community, both students and teachers, are already intense in using smartphones, so it is very appropriate if they make Augmented Reality (AR) technology a reality.

2. METHOD

2.1 Research and Development Procedur

This study uses a research and development (R&D) approach. R&D is used to produce certain products and can produce products used for needs analysis and curriculum research (Hanafi, 2017). The ADDIE (Analysis, Design, Development, Implementation, evaluation) is used as a development model. This method, in its use, has organized, orderly, and systematic stages to achieve the desired results.

The primary purpose of this development model is to design and develop an effective and efficient product (Benny A. Pribadi in WuIandari, 2018). This model consists of five steps, namely: (1) analyze, (2) design, (3) development, (4) implementation, and (5) evaluation (Widyastuti. E, 2019). Each step is explained as follows:

a. Analysis
   The first stage is, of course, the analysis stage; at this stage, what is being done is to identify what problems will be faced and what systems are suitable for solving these problems. At this stage also carried out the collection of data needed in the development of the system to be made.

b. Design
   The second stage after the analysis is the design stage, and this stage is the same as making a basic sketch. After identifying the problems that will be faced, the system design is carried out by solving problems that have been analyzed based on the data obtained. All preparations or designs must be clear and correct at the design stage.

c. Development
   After the design stage is complete and precise, the next stage is the development of the system, which has been analyzed in the analysis stage and designed in the design stage. This stage is the stage of

realizing the system sketch made at the design stage.

d. Implementation
The implementation stage can be referred to as the actual work stage. This means that the system that has been developed is applied at this stage.

e. Evaluation
The final stage in the ADDIE development model is the evaluation stage, carried out by checking or testing. This evaluation stage aims to see how the system works, and whether the system has been running well and has been as expected or not. At this evaluation stage, it assesses the system that has been made to produce revisions which will then be used as material for improvement.

2.2 Data Analysis Technique

Data analysis was carried out based on the results of questionnaires distributed to several selected respondents where each question on the questionnaire has its weight according to the provisions. The questions in the questionnaire are certainly related to the usability aspect of learning applications using Augmented Reality technology. The format used in this questionnaire also refers to the usability format, which is a quality attribute describing how easy it is to use an interface (Jacob Nielsen in Supriyatna 2018). The data from the questionnaire test with the usability format is then calculated based on the calculation formula:

$$Eligibility\ Percentage = \frac{overall\ score}{maximum\ score} x\ 100\%$$

The percentage of the calculation results using the above formula is then converted into a statement according to the following interval percentage table (Laswi A.S et all, 2022).

Table 1. *Percentage Range Interval*

No.	Percentage Interval	Criteria
1.	0% - 25%	Extreamly not worthy
2.	26% - 50%	Not worthy
3.	51% - 75%	worthy
4.	76% - 100%	Very worthy

3. RESULT AND DISCUSSION

3.1 Analisys

At this stage, a problem analysis was carried out at the research location, as well as collecting primary data through interviews with schooltt principals, teachers, and students. The results of the interviews that have been conducted include: 1) the learning process of solar system subjects at SMP 3 Rampi is only done verbally. 2) there are no learning media used in solar system subjects at the school, which means that a learning media is needed. 3)students' lack of interest in learning about solar system subjects. 3) the use of smartphones by students for the learning process has not been maximized, plus there is no cellular network or internet network. 4) Augmented Reality (AR) technology is still foreign and still unknown to almost all students and teachers at the research location.There are also secondary data in the form of learning materials by the curriculum used at the school; in this case, the material used is material on the solar system in science subjects (Natural Sciences) at the junior high school level and some material from the internet and relevant research that will be used in the development of learning applications using AR. From the results of this analysis, it was found that the solar

system material studied at the school would later be used as material for 3D solar system applications using Augmented Reality.

3.2 Design

The system description of augmented reality for learning the solar system is illustrated in the use case diagram that has been made (figure 1). The system description of this use case will be developed later. Then the sequence diagram will describe what the user can do with the menus/features available in the augmented reality application for learning the solar system; each menu is the tutorial menu (figure 2), quiz menu (figure 3), and the Scan menu or Augmented Reality markers menus (figure 4).

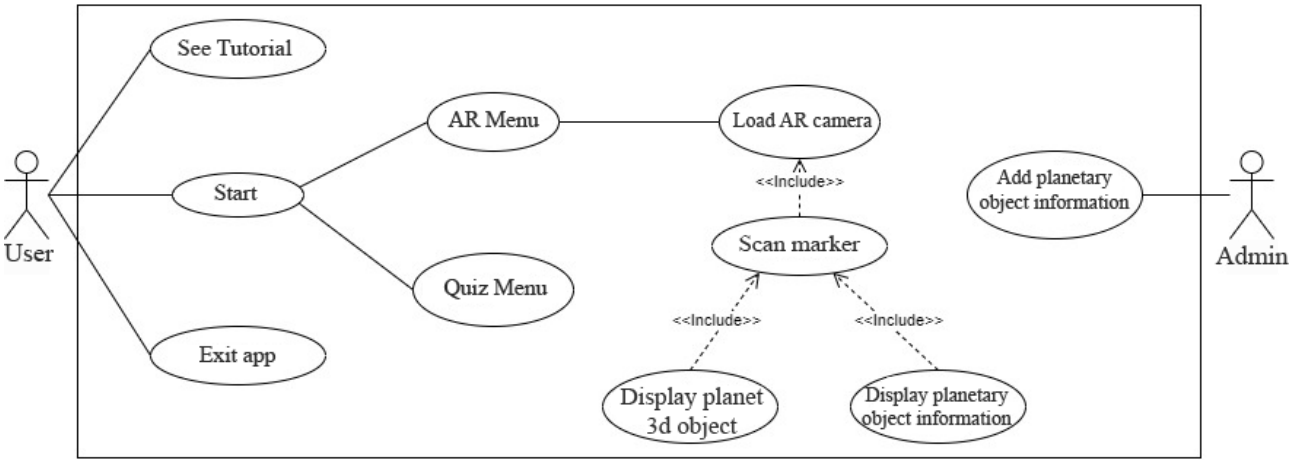

Figure 1 *Use case Diagram Augmented Reality for Solar System Learning*

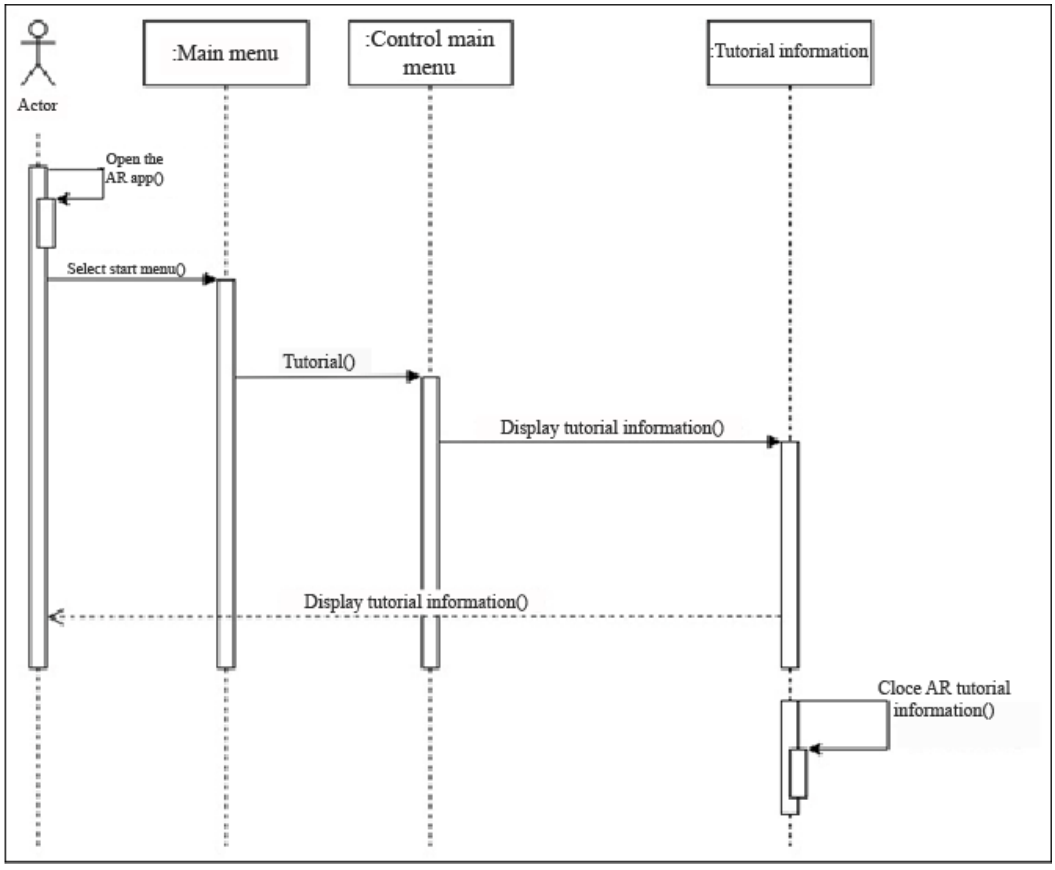

Figure 2 *Tutorial Menu Sequence Diagram*

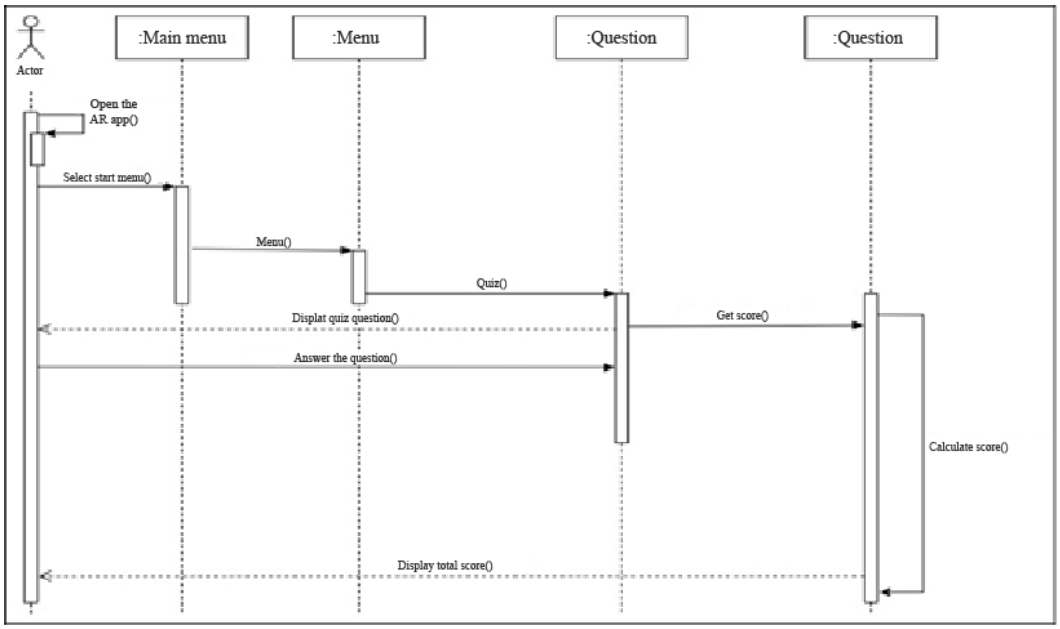

Figure 3 *Quiz Menu Sequence Diagram*

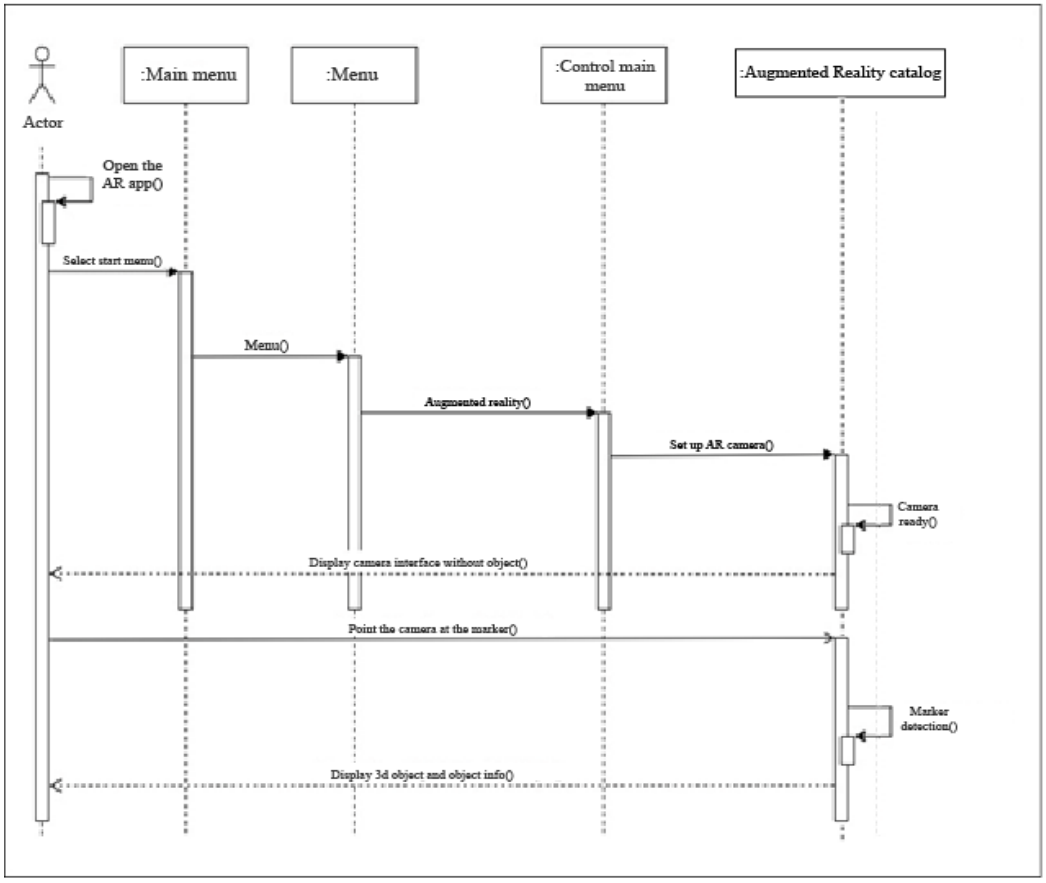

Figure 4 *Augmented Reality Menu Sequence Diagram*

After conducting interviews and direct observations, data was found in the form of several problems and solutions used to solve these problems using use cases and sequence diagrams. Then, a user interface display design was made, which can be seen in the figure below:

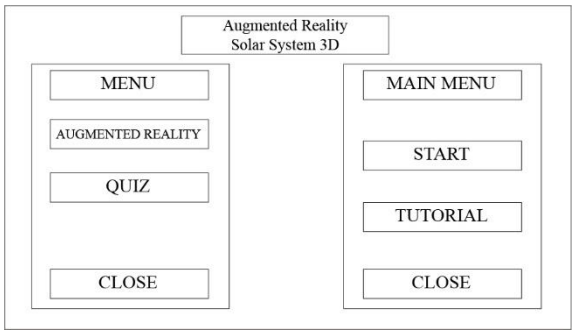

Figure 5 *Main menu*

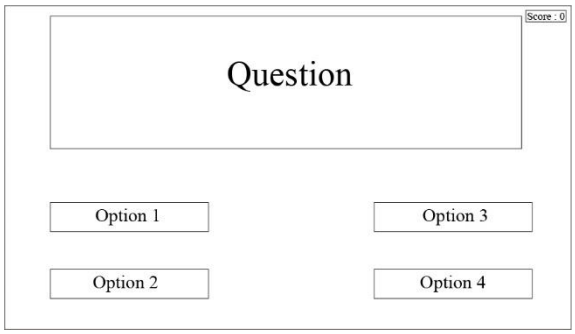

Figure 6 *Quiz menu*

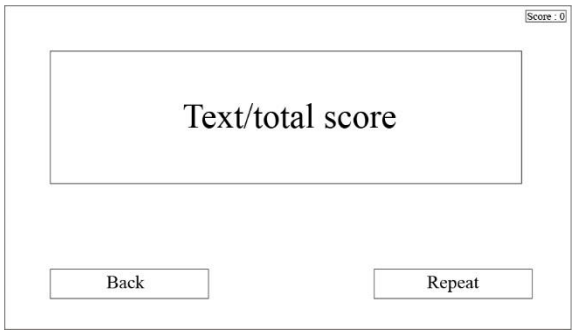

Figure 7 *Quiz menu (done)*

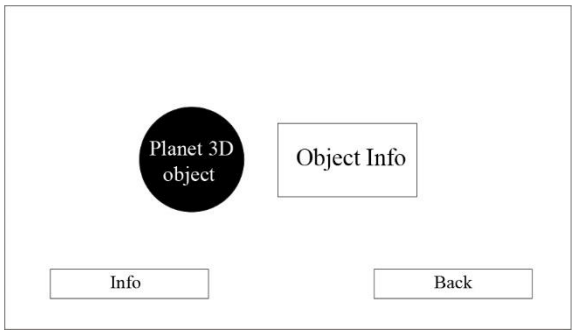

Figure 8 *Augmented Reality menu*

3.3 Development

The previously designed system is then developed using several software at this stage. For 3D models created using 3D Blender software, Blender is an open-source 3D computer software. This software creates visual effects, 3D models objects, video games, and 3D applications. Blender has features such as 3D modeling, texturing, and animation (Ardialis, 2019). Blender is a free and open-source 3D creation tool. Blender supports all 3D workflows, including modeling, rigging, animation, simulation, rendering, compositing and motion tracking, video editing, and game creation. Blender is very suitable for use by individuals as well as by small studios that are useful in 3D projects (Zebua T & Sinaga S). Blender is used to manufacture 3-dimensional planet objects apart from being free because it is straightforward and has all the tools needed to make 3-dimensional planet objects. The following is a display of a 3-dimensional planetary object created in 3D blender software:

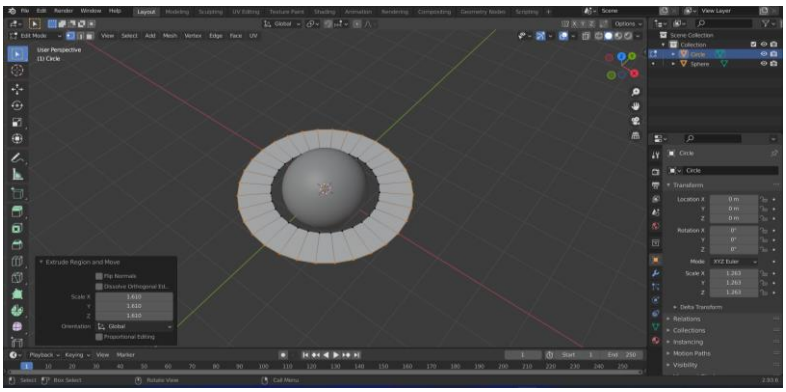

Figure 9 *3D Modeling in Blender 3D*

The user interfaces and Augmented Reality were developed using the Unity 3D software; Unity Co-founder and CEO 2013 revealed that Unity is a set of tools that can be used to build games with various technologies, including graphics, audio, physics, and interactions, and networking technologies. According to Helgason in (Irmanto 2018). Unity provides game development features on various platforms: Web, Windows, Mac, Android, iOS, Xbox, Playstation 3, and Wii. The agreement supports the creation of 2D and 3D games

but emphasizes more 3D. The programming languages used in Unity are JavaScript, C#, and BooScript programming languages (Rohmawati et all, 2019).The use of unity software in the development of AR applications for learning the solar system is based on the ability of the unity software to create user interfaces while presenting Augmented reality technology, which in its implementation is very easy to use. The following is the display of the user interface and the display when the user scans the marker to see the 3D object that has been created:

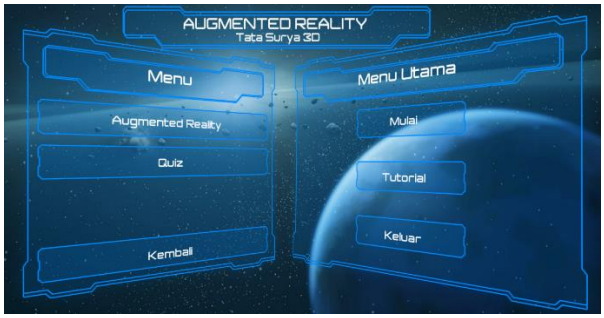

Figure 10 *Main menu*

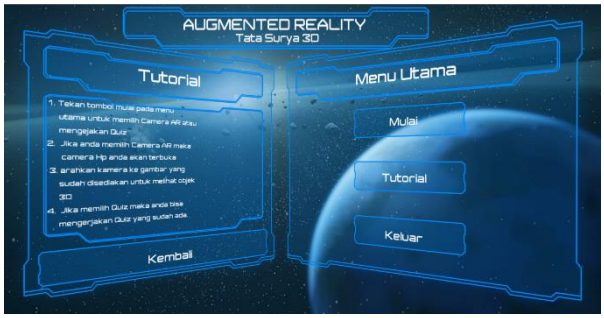

Figure 11 *Tutorial menu*

Figure 12 *Quiz menu*

Figure 13 *Augmented Reality menu*

Vuforia is an AR Software Development Kit (SDK) for mobile devices that enables the creation of AR applications. Vuforia SDK is also available to be combined with Unity, called Vuforia AR Extension for Unity. Vuforia is a Software Defelopment Kit (SDK) provided by Qualcomm to help developers create Augmented Reality (AR) applications on mobile phones (iOS, Android). The Vuforia SDK has been used in several mobile applications for both platforms (Puspitasari C et all, 2021).

Vuforia is Augmented Reality Software Development Kit (SDK) allows the creation or development of smartphone AR applications. Vuforia is an SDK provided by Qualcomm to help developers build and develop AR applications on the internet smartphones. besides that, vuforia also has many features and capabilities that can help developers realize developer thinking without limits. 3D world in real time (Ramadhan et all, 2021).

The development of AR applications for learning the solar system, the software is used as a database to store images and make these images as markers which will later be scanned using AR technology (figure 7). The software is Vuforia; this software is free and must be added to the Unity software to produce Augmented Reality applications that can run on mobile devices. Here is what the Vuforia database looks like:

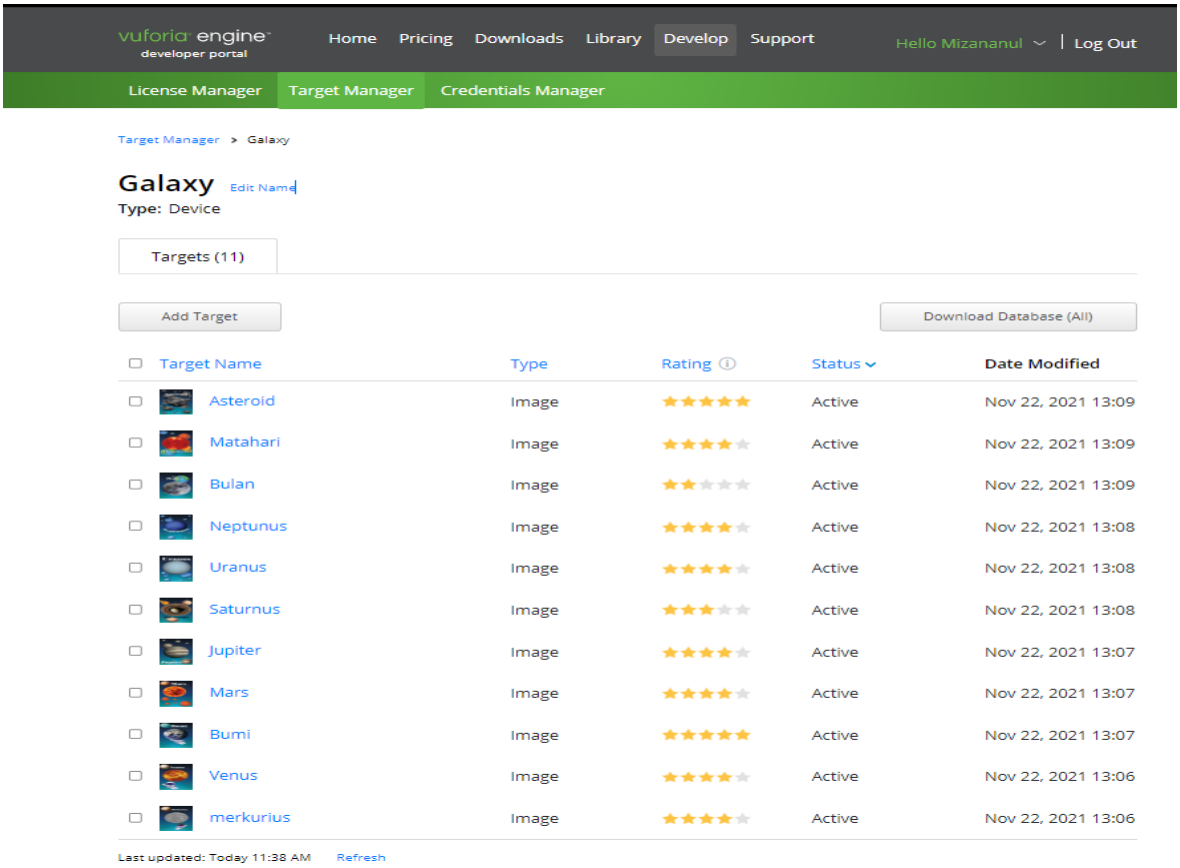

Figure 14 *Vuforia database*

3.4 Implementation

At the Implementation stage, the first thing to do is introduce what Augmented reality technology is. After the augmented reality application is installed on each student's and teacher's smartphone whit android platform, the learning process is carried out using augmented reality applications for learning the solar system. The learning process using augmented reality applications for learning the solar system between teachers and students runs smoothly; teachers and students are very enthusiastic when using the application; this is because they are experiencing and using AR technology added to the learning process of the solar system so far. Only use textbooks without other additional learning media.

3.5 Evaluation

After the implementation phase is complete, an evaluation is carried out using the previously described format. The weight of each question on the questionnaire that has been obtained and the results of the calculations are then displayed in the form of a table as follows:

Table 2. *Questionnaire calculation table*

respondent	indicator/variable																					Total Score	Max Score
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22		
1	4	4	4	4	4	3	3	3	3	4	3	3	3	3	4	3	3	4	3	3	3	3	74	88
2	3	3	3	3	3	3	3	3	4	3	4	3	3	3	3	3	3	3	3	3	4	4	70	88
3	4	3	4	4	4	3	3	4	4	4	4	4	4	3	4	4	4	3	3	4	3	3	80	88
4	3	4	3	3	3	3	4	3	3	3	2	3	4	3	4	3	3	4	3	4	4	4	73	88
5	4	3	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	3	4	85	88
6	4	3	4	4	4	4	4	3	4	4	3	4	4	4	4	4	4	4	4	4	4	4	85	88
7	4	4	4	4	4	4	4	4	3	3	3		4	4	4	4	4	4	4	4	4	4	81	88
8	4	3	4	3	4	4	3	4	3	3	4	3	4	3	4	4	4	3	4	4	3	4	79	88
9	3	3	4	4	4	3	4	3	4	3	3	4	4	3	4	4	4	4	4	4	3	3	79	88
10	4	4	4	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	86	88
Total																							792	880

The data calculated and displayed in the table is then calculated using the previously described formula. The calculation using this formula is as follows:

$$Eligibility\ Percentage = \frac{792}{880} x\ 100\%$$

From the calculation using this formula, a score of 90% is obtained; based on the interval table, the feasibility percentage of the results obtained is in the percentage range of 71% - 100%, with a very feasible category.

4. CONCLUSION

Based on the stages of research that have been carried out in making augmented reality applications for learning the solar system at SMPN 3 RAMPI, it can be concluded that:

1. Augmented reality applications for learning the solar system, which is in development using the software Blender, Unity, and the Vuforia plugin, have assisted the learning process to increase student interest in learning. They have been running correctly, as shown by the questionnaire results distributed to respondents with a score of 90%, which, if converted using an interval table, the proportion range is included in the very worthy category. This is an advantage of this research, considering that there were no learning media used before this research was conducted.
2. It should be noted that this Augmented Reality application for Solar System Learning can be run on smartphone devices with the Android operating system and cannot be run on devices with operating systems other than Android. This is a drawback as we know that smartphones currently circulating are not only devices with the Android operating system. Therefore, it is hoped that this application will be developed in the future so it can be run on multiplatform devices.

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Planning Pedestrian Paths for Trade and Service Areas of Balikpapan City with the Walkability Concept

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Keywords

Pedestrian Way; Walkability; Multicriteria Satisfaction Analysis; Photo Mapping Analysis; Balikpapan

Abstract

Corridor of the commercial area of Jalan MT. Haryono Balikpapan City specifically from the MT. Haryono Bridge to the Traffic Light Beruang Madu Monument has the characteristics of high mobility by motorized vehicles. Under these conditions, efforts are needed to encourage non-motorized movements. One of the efforts that have been made in the provision of pedestrian paths in the trade and service area. However, the lane has several problems, such as damaged sidewalks, motorized vehicles that often park around the sidewalks, and there are no guiding blocks for disabled users. Therefore, this study aims to plan a pedestrian path in the commercial area in the corridor of Jalan MT. Haryono uses the concept of walkability. This research uses walkability suitability analysis, community satisfaction level analysis, and Photo Mapping analysis. The results of the suitability analysis showed that segment 1 of the research area was not following the walkability and it was necessary to improve the pedestrian path infrastructure and add supporting facilities such as chairs, trash cans, CCTV, and shade plants, to guide blocks. While in segment 2, almost all of the variables are appropriate and require maintenance of several pedestrian path facilities. In the analysis of the level of community satisfaction using the Multicriteria Satisfaction Analysis, the planning priorities of the 4 walkability indicators are obtained. The results of this analysis show that segment 1 requires planning for the development of safety and comfort indicators, while segment 2 requires planning related to the development of safety and beauty indicators. The results of Photo Mapping show that it is necessary to add road barrier facilities, guiding blocks, parking ban signs, resting chairs, green lanes, repairing pedestrian lane infrastructure, and improving zebra crossing in segment 1. Segment 2 requires additional parking ban markers, speed bumps, chairs, trash cans, green paths, and care for weeds growing along the walkways

1. INTRODUCTION

The development of cities in Indonesia today causes an increase in movement activity which causes the city to become crowded (Nilayanti, 2012). The high activity of this movement causes the need for urban facilities to increase (Harahap, 2013). With this development, the government is required to be able to provide facilities and infrastructure to the community to support its activities (Abis, 2012).

The pedestrian path is a mandatory facility in urban planning. A pedestrian path is a facility made for people who do not use motorized vehicles. In essence, the pedestrian path is also the same as the vehicle path, namely as a container or community facility for moving places. In addition, the pedestrian path is also a public space that can create social interaction. Pedestrian paths are concerned with pedestrian safety aspects so that they can feel safe and comfortable passing through the lane. This is supported by article 25 of Law no. 22 of 2009 every public traffic lane must be equipped with lanes for people with special needs (disabled).

Balikpapan City is located in East Kalimantan Province and is a city that is often visited by outsiders so Balikpapan City is a dense city. The city of Balikpapan has a role in increasing the density of the city, especially for the use of land that functions as a trade and service area. This trade and service area has an impact on increasingly congested traffic conditions due to activities in this area and makes movement activities in this area more crowded. Vehicles that crowd this area will have an impact on the movement in this area (Siswanto, 2015).

In the South Balikpapan sub-district, there is Jalan MT Haryono which is located between 3 villages, namely Damai Village, Damai Bahagia Village, Damai Baru Village, precisely along the road from MT Haryono Bridge to Simpang Lampu Merah Tugu Bear Madu which is a trade and service area that has been listed on the RTRW years 2012-2032. This area is dominated by trade and service activities which cause quite high attraction and generation (Meytika, 2020). However, the pedestrian facilities on this road are inadequate, such as the damage to some sidewalks, the size that looks small, vehicles using pedestrian paths as parking lots, so that there are no Guiding Blocks (disabled lanes) for people with special needs, which is not appropriate. with the guidelines for the 2018 PUPR Ministry Pedestrian Technical Planning. Road Corridor. Haryono is often passed by the community, especially at lunchtime and coming home from work. This, in addition to endangering users, can also reduce public interest in walking, causing congestion.

One of the concepts in pedestrian path planning that can solve this problem is walkability which has a planning focus on determining facilities for sidewalk users that prioritizes aspects of safety and comfort for users in carrying out activities. (Ayu, 2020). This concept is a concept that has been widely used in several cities in Indonesia such as Depok City, Salatiga City, and Jakarta City.

From the above problems, research is needed to formulate recommendations for pedestrian paths with the concept of walkability on order to pay attention to the public to use pedestrian paths according to their functions and reduce traffic congestion, so that it can be a consideration for the Balikpapan city government towards pedestrian paths. With this analysis, it can be seen that the level of community satisfaction with the pedestrian path in this corridor is related to the walkability

2. METHODS

Data collection techniques from this study were in the form of a primary survey and the results of a pedestrian path user questionnaire. By using 2 research segments, namely from the MT Bridge. Haryono to the Pertamina gas station intersection along ±426 M is segment 1 and the Pertamina gas station Interchange to the Sun Bear Monument Red Light along ±588 M is segment 2. The total distance of the study is ±1.014 Km.

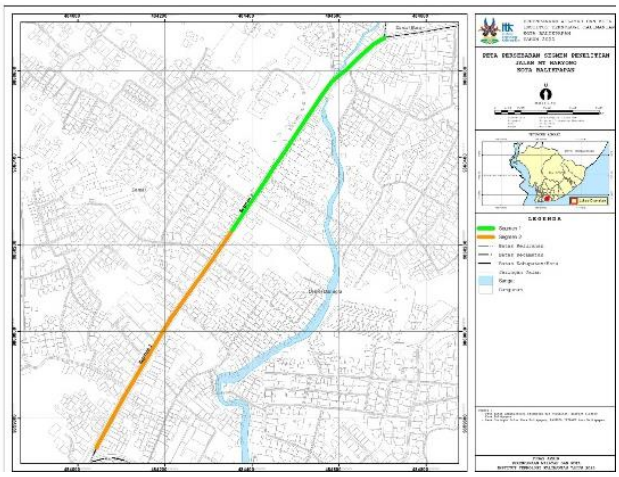

Figure 1. Research Segment Map
Sources: Primary Survey, 2022

The sample of this study is all users of pedestrian paths along the pedestrian paths in the trade and service area on Jalan MT. Haryono uses the method of determining the sample as purposive sampling where this method considers certain things to determine the target sample. The provisions needed from the research sample are people who are over 17 years old and are users of pedestrian paths in the research area. The total sample used is based on the results of calculations using the Bernoulli method, which is 96.04 which is rounded up to 100 samples. This method is used because it is not known with certainty the number of pedestrian path users in the research area and is strengthened by the theory which reads For conditions where the exact number is not known, 100 respondents in the research area can be used (Tan, 2014). Of the 100 respondents, they were

divided based on the research segment, namely 50 for segment 1 with a composition of 25 respondents for the right and left sides and 50 for segment 2 with the same composition.

The variables of this study refer to 4 indicators of walkability, namely security, comfort, safety, and beauty. The following is a table of variables for each indicator

Table1. Variable for Research

Indicator	Variable
Security	1. Pedestrian Line Conflict with Other Transportation Modes
	2. Availability of Pedestrian Paths
	3. Crossing Availability
	4. Constraints/Obstacles
	5. Security Against Crime
Convenience	1. Supporting Facilities
	2. Disability Supporting Infrastructure
Safety	1. Crossing Security
	2. Rider Behavior
Beauty	1. Support Facility
Sources	*Author's Analysis, 2022*

3. RESULT AND DISCUSSION

This study has 3 results of the analysis that are considered as recommendations for planning pedestrian paths on Jalan MT. Haryono Balikpapan City. The first is to find out the suitability of existing conditions with the concept of walkability based on the author's perception based on facilities supporting the concept of walkability, to determine the level of community satisfaction by using the Multicriteria Satisfaction Analysis to find out what indicators of walkability require planning recommendations. With this method, it is possible to know more deeply about the level of community satisfaction with the walkability, and the last is a descriptive photo mapping analysis to be able to provide planning recommendations on the results of the community satisfaction level with the walkability indicator. The following is a discussion of the results of the analysis

3.1 WALKABILITY CONFORMITY ANALYSIS

The results of this analysis indicate the existing condition of the research area on walkability. Suitability table for walkability of each research segment

Table 2. Result of the Walkability Conformity Analysis of Segment 1 Left Side

Indicator	Variable	Match /Not Match
Security	Conflict of Pedestrian Paths with Other Transportation Modes	Not Match
	Availability of Pedestrian Paths	Match
	Availability of Crossings	Match
	Constraints/Barriers	Not Match
	to Crimes	Not Match
Comfort	Supporting Facilities	Not Match
	Infrastructure Supporting Disabled	Not Match
Safety	Security Crossings	Not Match
	Behavior of Riders	Not Match
Aesthetic	Supporting Facilities	Not Match
	Sources	*Author's Analysis, 2022*

Table 3. Result of the Walkability Conformity Analysis of Segment 1 Right Side

Indicator	Variable	Match/Not Match
Security	Conflict of Pedestrian Paths with Other Transportation Modes	Not Match
	Availability of Pedestrian Paths	Match
	Availability of Crossings	Match
	Constraints/Barriers	Not Match

Indicator	Variable	Match/Not Match
	to Crimes	Not Match
Comfort	Supporting Facilities	Not Match
	Infrastructure Supporting Disabled	Not Match
Safety	Security Crossings	Not Match
	Behavior of Riders	Not Match
Aesthetic	Supporting Facilities	Not Match
	Sources	*Author's Analysis, 2022*

Table 4 Result of the Walkability Conformity Analysis of Segment 2 Left Side

Indicator	Variable	Match /Not Match
Security	Conflict of Pedestrian Paths with Other Transportation Modes	Not Match
	Availability of Pedestrian Paths	Match
	Availability of Crossings	Match
	Constraints/Barriers	Match
	to Crimes	Match
Comfort	Supporting Facilities	Not Match
	Infrastructure Supporting Disabled	Not Match
Safety	Security Crossings	Match
	Behavior of Riders	Match
Aesthetic	Supporting Facilities	Match
	Sources	*Author's Analysis, 2022*

Table 5. Result of the Walkability Conformity Analysis of Segment 2 Left Side

Indicator	Variable	Match /Not Match
Security	Conflict of Pedestrian Paths with Other Transportation Modes	Not Match
	Availability of Pedestrian Paths	Match
	Availability of Crossings	Match
	Constraints/Barriers	Match
	to Crimes	Match
Comfort	Supporting Facilities	Not Match
	Infrastructure Supporting Disabled	Match
Safety	Security Crossings	Match
	Behavior of Riders	Match
Aesthetic	Supporting Facilities	Match
	Sources	*Author's Analysis, 2022*

From the results of the analysis above, it can be concluded that the condition and availability of pedestrian path facilities for each walkability in segment 1 are still not suitable and require additional maintenance of pedestrian path facilities. In segment 2, research on the condition and availability of pedestrian path facilities for each walkability is almost all appropriate, but for the variable supporting facilities, it is not appropriate and requires addition and maintenance of pedestrian path facilities. The following is a list of table variables that do not match

Table 6. Inappropriate Research Variables

Segment	Sides	Variable
Segment 1	Left	1. Pedestrian Path Conflicts With Other Transportation Modes 2. Obstacles/Obstacles 3. Security Against Crime 4. Supporting Facilities 5. Disabled Supporting Infrastructure 6. Crossing Security 7. Rider Behavior 8. Supporting Facilities

Segment	Sides	Variable
Segment 2	Right	1. Pedestrian Path Conflicts With Other Transportation Modes 2. Obstacles/Obstacles 3. Security Against Crime 4. Supporting Facilities 5. Disabled Supporting Infrastructure 6. Crossing Security 7. Rider Behavior 8. Supporting Facilities
	Left	1. Pedestrian Route Conflict with Other Transportation Modes 2. Supporting Facilities 3. Disabled Supporting Infrastructure
	Right	1. Pedestrian Path Conflicts With Other Transportation Modes 2. Supporting facilities

Sources: Author's Analysis, 2022

3.2 COMMUNITY SATISFACTION LEVEL ANALYSIS

This analysis uses the Multicriteria Satisfaction Analysis which produces an action diagram in the form of 4 quadrants. This diagram is a consideration of the planning priorities of the 4 walkabilities. The output of this analysis has an action diagram with 2 input diagrams, namely importance in the form of respondents' results and performance in the form of results from researchers. Here are the results of the analysis

Table 7. Results of Analysis of the Percentage of Community Satisfaction Levels and Researcher Assessment of Segment 1 Left Side

Indicator	Average of Importance	Average of Performance
Security	51%	45%
Comfort	49%	25%
Safety	50%	38%
Aesthetic	54%	50%
	Sources	*Author's Analysis, 2022*

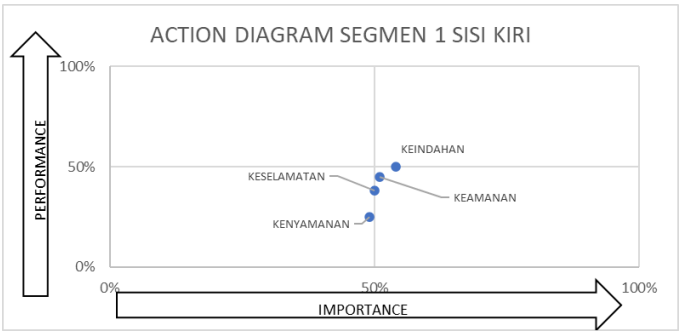

Figure 2. Action Diagram Segment 1 Left Sides
Sources: Author's Analysis, 2022

The results of the above analyses show that indicators that require planning priority are security indicators.

Table 8. Results of Analysis of the Percentage of Community Satisfaction Levels and Researcher Assessment of Segment 1 Right Side

Indicator	Average of Importance	Average of Performance
Security	57%	50%
Comfort	55%	35%
Safety	55%	50%
Aesthetic	55%	50%
	Sources	*Author's Analysis, 2022*

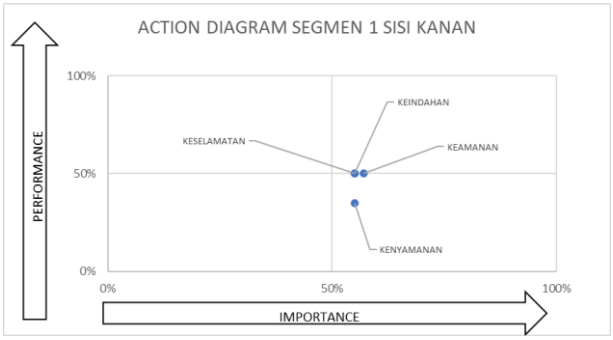

Figure 3. Action Diagram Segment 1 Right Side
Sources: Author's Analysis, 2022

The results of the above analyses show that indicators that require planning priority are comfort indicators.

Table 8. Results of Analysis of the Percentage of Community Satisfaction Levels and Researcher Assessment of Segment 2 Left Side

Indicator	Average of Importance	Average of Performance
Security	48%	65%
Comfort	45%	38%
Safety	51%	75%
Aesthetic	45%	50%
	Sources	*Author's Analysis, 2022*

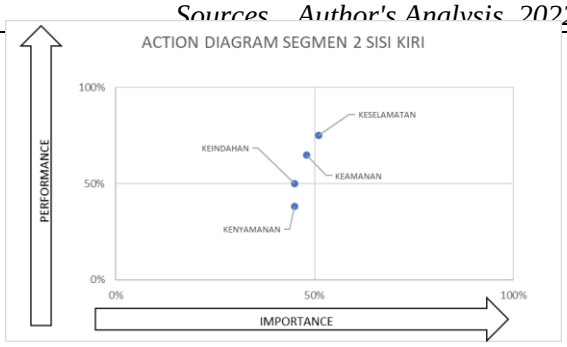

Figure 4. Action Diagram Segment 2 Left Sides
Sources: Author's Analysis, 2022

The results of the above analyses show that indicators that require planning priority are safety indicators.

Table 8. Results of Analysis of the Percentage of Community Satisfaction Levels and Researcher Assessment of Segment 2 Right Side

Indicator	Average of Importance	Average of Performance
Security	50%	55%
Comfort	51%	50%
Safety	54%	75%
Aesthetic	52%	22%
	Sources	*Author's Analysis, 2022*

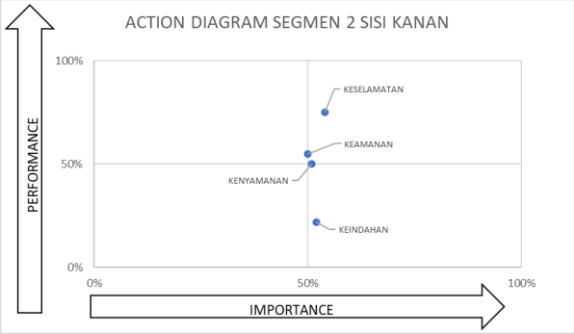

Figure 5. Action Diagram Segmen 2 Right Sides
Sources: Author's Analysis, 2022

The results of the above analyses show that indicators that require planning priority are aesthetic indicators.

3.3 PHOTO MAPPING ANALYSIS

Planning Pedestrian Paths for Trade and Service Areas of Balikpapan City with the Walkability Concept After obtaining the direction for the development of the action diagram for each research segment, then a photo mapping analysis is carried out to find out which parts require the development of the research segmentation by considering the existing photos of the research area. . This analysis is useful to be able to provide development recommendations related to the existing condition of research segmentation by providing an overview and development recommendations.

The results of the analysis of community satisfaction show which indicators require planning recommendations for each research segment. The following are indicators that require planning recommendations

Table 9. Indicator of Planning

Segment	Segment Sides	Indicator
Segment 1	Left	Security
	Right	Comfort
Segment 2	Left	Safety
	Right	Aesthetic
	Sources	*Author's Analysis, 2022*

After knowing what indicators require planning recommendations for each research segment, then a review of the existing conditions is carried out following the condition of the pedestrian facilities for each indicator and provides planning recommendations. The following is a photo mapping for the two research segments

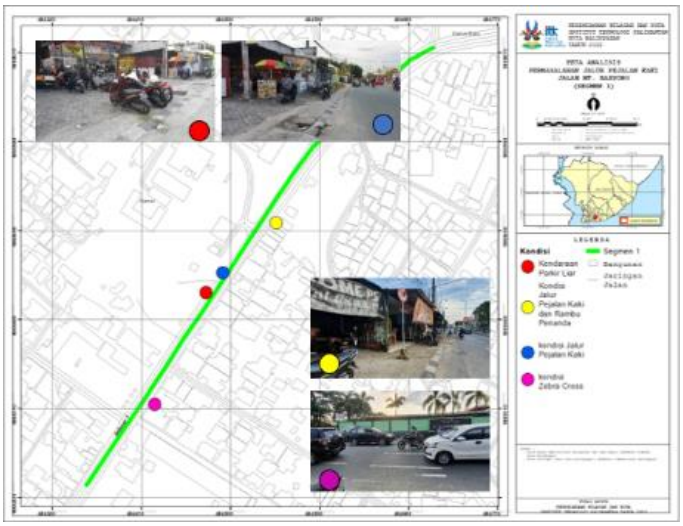

Figure 6. Photo Mapping Segment 1
Sources: Author's Analysis, 2022

Segment 1 of the study from the results of the analysis of the level of community satisfaction on the left and right sides explains that the walkability indicators that require planning recommendations are indicators of safety and comfort. For security indicators, several improvements were made, such as the condition of damaged road infrastructure and the provision of road barriers, repairing zebra crossings, controlling street vendors' activities, and providing security facilities such as CCTV and security posts. For comfort indicators, it is necessary to add signage/marking boards such as parking restrictions, provision of seats, repair of plant pots, and building pathways for people with disabilities, namely guiding blocks/guiding tiles. The following are recommendations for segment 1.

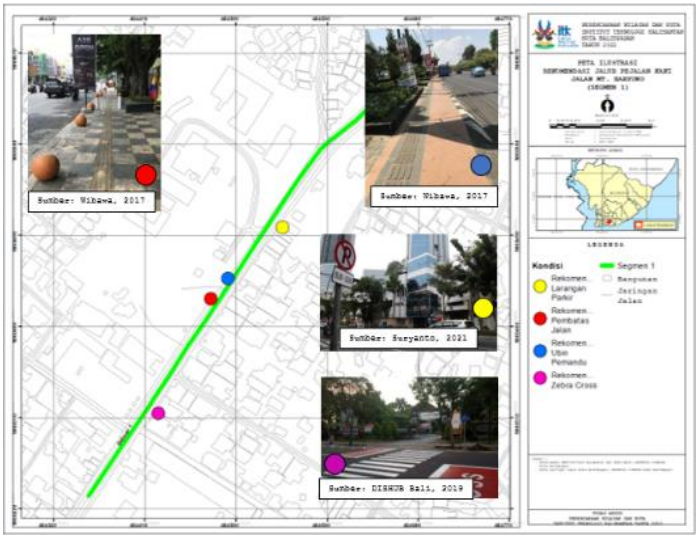

Figure 7. recommendations for Segment 1
Sources: Author's Analysis, 2022

One of the road planning recommendations in this segment is the improvement of pedestrian path infrastructure which can take an example such as on Jalan Soegijapranata, Semarang City with pavement using tiles and equipped with *blocks/*guiding tiles. To prevent parking on pedestrian paths, bollards can be provided, such as on Jalan Imam Bonjol, Semarang City, and prohibition of parking at crowded times, such as on Jalan Tunjungan, Surabaya. Furthermore, crossing facilities can be planned as in the picture where there is ZOSS (Zona Selamat Sekolah) because the position of the *zebra cross is* close to Kartika Kindergarten such as on Jalan Danadak, Denpasar City

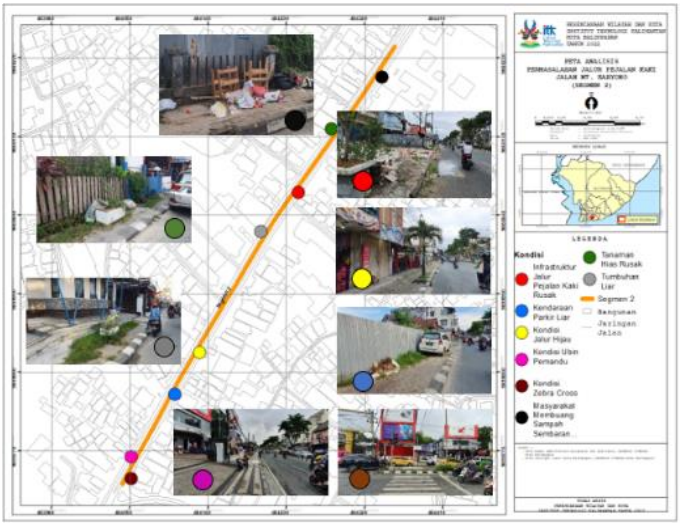

Figure 8. Photo Mapping Segment 2
Sources: Author's Analysis, 2022

Segment 2 of the research from the results of the analysis of the level of community satisfaction on the left and right sides explains that the walkability indicators that require planning recommendations are safety and beauty indicators. For security indicators, maintenance related to infrastructure is needed, and the addition of bollards and parking restrictions on pedestrian paths so that access to the zebra cross is not blocked by vehicles parked carelessly. For indicators of beauty, it requires to care for ornamental plants and wild plants as well as providing trash cans so that there is no littering activity on pedestrian paths. It is also necessary to repair the damaged pedestrian path infrastructure

Figure 9. recommendations for Segment 2
Sources: Author's Analysis, 2022

One of the planning recommendations that can be applied to segment 2 is repairing damaged pedestrian lane infrastructure such as the example on Jalan Soegijapranata Semarang City and planning to overcome illegal parking is to provide road barriers in the form of bollards such as on Jalan Imam Bonjol Semarang City. Furthermore, recommendations for green line problems can be rearranged with simple concepts such as on Jalan Ahmad Yani, Semarang City. Furthermore, for waste problems in this segment, you can add trash bins with a maximum distance of 10 meters, such as on Jalan Pengran Diponogoro, Central Jakarta Province.

4. CONCLUSIONS

Research has been carried out related to pedestrian paths in the trade and service area of Jalan MT. Haryono, Balikpapan City, precisely along the MT Bridge road corridor. Haryono to the Red Light of the Sun Bear Monument.

suitability analysis walkability shows that segment 1 for the comfort and safety indicators is not following the supporting variables for these indicators, so it requires some planning recommendations for these indicators. For segment 2, most of the variables of each indicator are following the concept of walkability planning.

The results of the analysis of the level of community satisfaction in segment 1 on the left side show that the security indicator has a low level of satisfaction and the action diagram is an indicator that requires follow-up in providing planning recommendations. For segment 1, the right side shows comfort indicators requiring follow-up in providing planning recommendations. Furthermore, segment 2 on the left side shows safety indicators that need maintenance and the addition of several pedestrian path facilities. Finally, for segment 2, the right side shows that beauty indicators require follow-up in providing planning recommendations.

The results of the photo mapping to provide planning recommendations in segment 1 are recommendations for security indicators that require several improvements such as the condition of damaged road infrastructure materials and the provision of road dividers, zebra crosses, controlling the activities of street vendors, and providing security facilities such as CCTV and security posts. For comfort indicators, it is necessary to add signage/marking boards such as parking restrictions, giving seats, repairing plant pots, and building paths for people with disabilities, namely blocks/guiding tiles. Segment 2 requires recommendations for security indicators, maintenance related to infrastructure, and the addition of bollards and parking restrictions on pedestrian paths so that access to the zebra cross is not blocked by vehicles parked carelessly. For indicators of beauty, it requires to care for ornamental plants and wild plants as well as providing trash cans so that there is no littering activity on pedestrian paths. It is also necessary to repair the damaged pedestrian path infrastructure

5. ACKNOWLEDGMENTS

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The Concept of Development of Ex-Mining C Mine in Wonosobo Regency

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Keywords

C Mine; Development Concept; Wonosobo Regency

Abstract

The development of ex-mining land needs to be carried out to preserve the environment and make an alternative to sustainable, beneficial, and efficient use of ex-mining land. This study aims to provide an alternative concept for the development of ex-mining C excavation in Kertek District and Mojotengah District in Wonosobo Regency so that ex-mining land can still have economic value but is sustainable from the physical and environmental aspects. This research used a SWOT analysis technique. Data analysis was carried out from the results of collecting field facts and secondary data to identify existing conditions and ideal conditions to be achieved, as well as through alternative studies by identifying and analyzing segmentation based on land use, location, and existing conditions. The results of the study resulted in the concept of Eco-community Highland Tourism. This concept is to develop an area with high environmental quality and human resources, driven by the tourism sector as a priority. This concept contains the principles of improving environmental quality, economic sustainability, community empowerment, and the development of the tourism sector by the upland agricultural sector.

1. INTRODUCTION

Wonosobo Regency is one of Central Java Province with great potential for natural resources, one of which is sand and rock mining. That is inseparable from the natural topography of the area in the form of mountains. Wonosobo Regency has two volcanoes on the east side, namely Mount Sindoro with a height of 3,136 meters and Mount Sumbing with an altitude of 3,371 meters. In addition, there is also Mount Prau, the peak of the Dieng Plateau with a height of 2,565 meters, located on the north side (Nugroho, 2020). With these topographical conditions, Wonosobo Regency is also rich in springs and fertile land used for agricultural activities.

The role of mining activities in supporting the economy can create new job opportunities, but it can also impact social unrest and environmental sustainability. In 2017, the Wonosobo Regency Government issued Regional Regulation Number 12 of 2017 concerning the revocation of Wonosobo Regency Regional Regulation Number 6 of 2007 concerning Group C Mining Business. That is a follow-up to the Central Java Governor Decree Number 180/114 of 2016. Aspirations of the local community regarding the impact of mining activities and the sustainability of the local environment accommodate.

Geologically, Wonosobo Regency has abundant minerals from volcanic activities such as andesite lava and tuff. Rock minerals found in Wonosobo Regency include mica schist, marl, sandstone, quartz conglomerate, sand and river stone, pumice breccia, and andesite. These rock excavations are in hilly areas, except for sandstone and some marl, often in river valley areas. The excavation material for backfill is not only found in areas with hilly topography but also in flat areas.

Mining activities are closely related to environmental damage. Management of ex-mining lands with excellent and appropriate principles is vital to paying attention to the biotic and abiotic environment and the processes in the land at each level. In addition, managing ex-mining land is very important to overcome

environmental damage from the loss of vegetation, flora, fauna, and soil layers (Patiung, Naik, Suria, & Dudung, 2011; Taqiyuddin & Hidayat, 2020).

Management of ex-mining land has been mandated in Law Number 4 of 2009 concerning Mineral and Coal Mining, Government Regulation Number 22 of 2010 concerning Mining Areas, and Government Regulation Number 78 of 2010 concerning Reclamation and Post Mining. Reclaiming ex-mining land at least it can make the landscape return to its original state, although it may not be able to restore its biodiversity precisely as it used to be. This effort can also reduce the risk of landslides and other disasters caused by the destruction of an ecosystem. The implementation of reclamation is no later than one month after there are no more mining business activities on the land. Meanwhile, the report on the implementation of reclamation is carried out every year to the governor (Octavia, 2017).

Several studies show that post-mining land management results need sustainable development-based use (As'ari, Mulyanie, & Rohmat, 2019; Kurniawan, 2013). Post-mining land management, especially in using ex-sand mining land, is recommended following the criteria for utilization and management, one of which is in the nature-based tourism sector. The activities in developing nature-based tourism include educational forests, recreational parks, artificial lakes, resorts, beaches, and museums. Through the development of nature-based tourism, the land will have economic value. However, it needs to be encouraged through community participation and requires government institutions and policies (Haridjaja, Haryanti, & Oktaviani, 2013).

Therefore, to achieve sustainable, valuable, and efficient use of ex-mining land, it is necessary to conduct a study on the use of ex-mining land in the Wonosobo Regency. This study aims to provide an alternative concept for the development of ex-mining land. Especially in the use of ex-sand mining land (excavation C) in Wonosobo Regency. So that the ex-mining land can still be of economic value but sustainable from the physical and environmental aspects.

2. METHOD

This study aims to provide alternatives related to the development of ex-mining areas c so that ex-mining areas can still have economic value but are sustainable from the physical and environmental aspects. The research location is in Kertek District and Mojotengah District, Wonosobo Regency. This area consists of 7 villages: Candiyasan Village, Pagerejo Village, Tlogomulyo Village, Damarkasian Village, Tlogojati Village, Sojopuro Village, and Keseneng Village, with a total area of 570 hectares.

This research used SWOT (Strength, Weakness, Opportunity, Threat) analysis. SWOT is a strategic planning method used to evaluate the factors that become strengths, weaknesses, opportunities, and threats that may occur in achieving goals in an organizational activity project on a broader scale. For this purpose, it is necessary to study environmental aspects, both the internal and external environments, that affect the pattern of organizational strategy in achieving goals (Rangkuti, 2008).

Previous studies have shown that a similar research approach can formulate alternative regional and urban development strategies. The study's SWOT analysis technique is to formulate urban planning, city development, and regional development strategies (Adriansyah, 2013; Masrurun, 2020; Siregar, Hariani, & Widowati, 2013).

SWOT analysis is a powerful instrument for conducting a strategic analysis. This efficacy lies in the ability of strategy makers to maximize the role of strength factors and take advantage of opportunities to simultaneously act as a tool to minimize weaknesses and reduce the impact of threats that arise and must be faced (Apriandes, Ranius, & Syakti, 2013). SWOT analysis has several advantages. Namely, the SWOT analysis model can detect every weakness and strength so that it helps minimize the impact or consequences that will occur in the future. Analysis of internal and external factors is a SWOT analysis method that can identify existing internal and external factors. Furthermore, it can be known internal and external factors that will affect it (Subaktilah & Kuswardani, 2018).

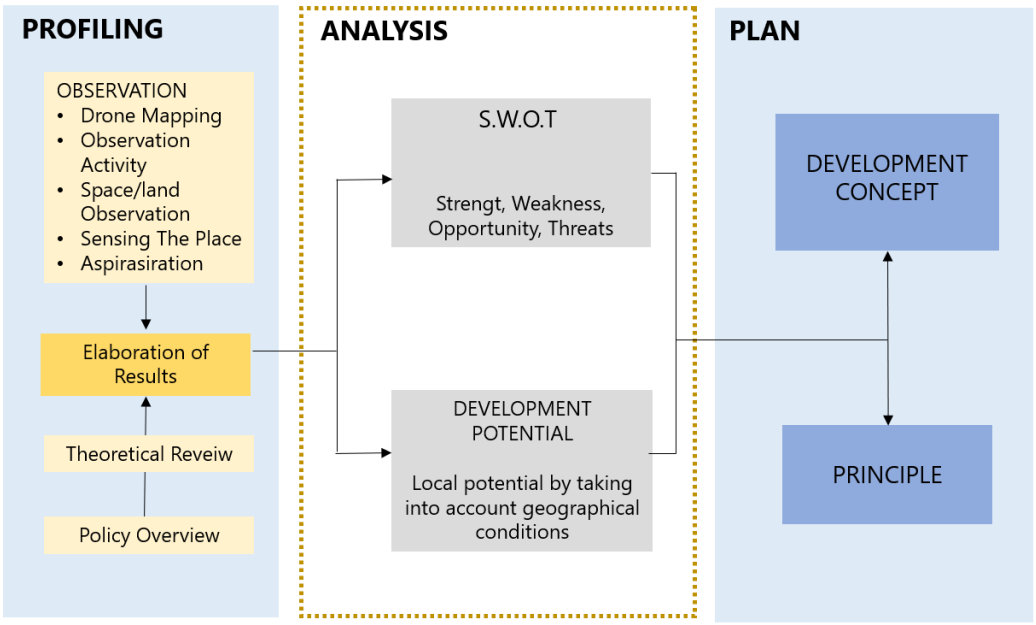

Figure 1. Research Flow

The research stages are through observation, review of previous planning documents in the area, regulatory review, and normative review, then elaborated on the aspirations of stakeholders regarding the use and development of the area. Data analysis was carried out from the results of collecting field facts and some secondary data to identify existing conditions and ideal conditions to be achieved, as well as through alternative studies by identifying and analyzing segmentation based on land use, location, and existing conditions. The formulation of the development concept has based on an analysis of the area's potential and SWOT analysis. The development concept is then detailed in the design principles to support and simplify the description of the development concept.

3. RESULT AND DISCUSSION

3.1 Overview of The Research Area

The ex-mining area is under the administration of Kertek District and Mojotengah District, Wonosobo. This area is mountainous, with an average altitude of 700 - 1,400 meters above sea level. In general, the planning area has a dominant land use in the form of fields and tea plantations that are fertile and productive. In addition, there are natural tourism activities and non-metallic mineral and rock type mining activities of sand and stone, which are massive.

The total population in the area is 17,408 people. The mining sector is a side job for farmers as mining workers or renting out their land. In the area, several tourist destinations attract visitors, as well as residents, who take advantage of these tourist visits by building selling stalls. This area includes seven villages with an area of approximately 570 hectares. The seven villages include Candiyasan Village, Pagerejo Village, Tlogomulyo Village, Damarkasian Village, Tlogojati Village, Sojopuro Village, and Keseneng Village. This area has a slope dominated by flat slopes (0-8) % and gentle slopes (8-15) %. The regional slope reference is classified into five types, namely as follows:

Table 1. Reference for Regional Slope Classification and Scoring

Class	Slope (%)	Classification	Score
I	0 – 8	Flat	20
II	8 – 15	Sloping	40
III	15 – 25	Slightly Steep	60
IV	25 – 45	Steep	80

V	> 45	Very Steep	100

Source: Decree of the Minister of Agriculture No. 837/KPTS/UM/11/1980

3.2 Area Condition Analysis

The dominance of land use in the area is agriculture and plantations. In addition, there are mines excavated C, settlements, and the use of the area as a tourist attraction at several points. The utilization and development of tourist attraction objects also affect the community's economic activity by utilizing the land to open roadside stalls around developing tourist attractions. That can be around the tourist attraction of Mount Cilik and Mount Kembang climbing basecamp. The private sector has also begun to develop the use of existing land in the area by building tourism supports such as rest areas at strategic points.

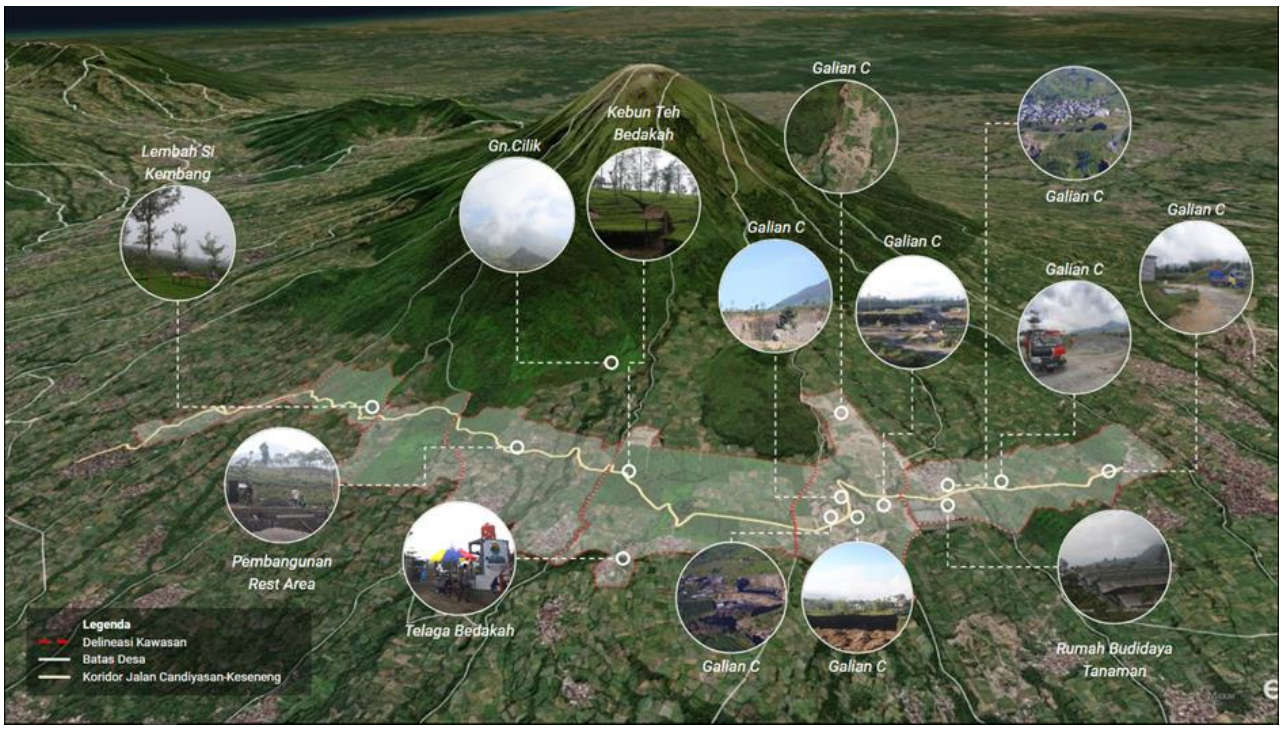

Figure 2. Land Use

Based on the existing conditions in the area, the tourism sector is one of great potential in the area to direct the use and conversion of land to productive economic sectors other than mining. The development of the tourism sector can also improve the supply chain in the agricultural and plantation sectors in the region in a sustainable manner through sustainable tourism. The World Tourism Organization (UNWTO) states that Sustainable Tourism is tourism that takes complete account of the current and future economic, social and environmental impacts and can meet the needs of visitors, industry, the environment, and communities in tourism destinations (Kemenparekraf, 2012).

So that it is reviewed based on the potential for development in the scope of the area, the development of ex-excavated C land in the sustainable tourism sector is needed as the utilization and conversion of land in other productive economic sectors that can replace the current sand mining. In addition, tourist attractions have developed in the area, such as Bedakah tea gardens, Bedakah Lake, Mount Kembangan climbing, Mount Cilik tourism, and Sikembang Valley tourism, which can support, integrate, and provide economic, social, and environmental impacts on the area.

3.3 SWOT Analysis

A SWOT analysis evaluates the strengths, weaknesses, challenges, and opportunities that exist through four strategic approaches that can respond to field conditions.

Table 2. SWOT Analysis

Internal / External	Strengths (S)	Weaknesses (W)
	1. Strategic location to be developed into a tourist destination and economic potential 2. Has a diversity of landscapes that can be optimized as a natural tourist attraction 3. Has an existing tourist attraction Mount Bunga, Tambi tea plantation, and a small mountain, Bedahkah Lake 4. Most of the existing road infrastructure is paved and concrete	1. Road support furniture is not adequate for road users (lighting, signage, road safety, signs) 2. There are non-agricultural activities that tend to damage the environment 3. Mining activities that hinder community economic activities 4. Candiyasan-Keseneng Road Corridor has not been fully developed
Opportunities (O) 1. The area connects the activity poles (Kertek and Dieng tourism alternative roads) 2. Mining land and activities can be converted into commercial and tourism potential. 3. Close to existing tourist areas (Posong, Kledung, Lengkong) 4. There is the development of the Candiyasan - Keseneng road corridor	**S-O Strategy** 1. Development of existing geographic and natural resource potential by looking at opportunities from new economic sectors 2. Development of transportation facilities to support various interests (public, tourism, and distribution of agriculture and plantations) 3. Development of existing tourist attractions by maximizing tourism attractiveness around the area	**W-O Strategy** 1. The conversion of mining land into a productive economic activity that pays attention to the environment 2. Provision of road support furniture for the safety of road users in the area 3. Continuing the construction of the road connecting the Candiyasan-Keseneng corridor
Threats (T) 1. Investors who will develop land around the ring road have an impact on the sustainability of plantations and fields, the risk of landslides, and scenic views 2. Uncontrolled expansion of non-agricultural activities	**S-T strategy** 1. Control of land use and activities in the planning area and its surroundings 2. Maintaining natural sustainability while minimizing uncontrolled development	**W-T Strategy** 1. Assistance to the community to preserve nature and improve environmental conditions 2. There is a need for disaster mitigation efforts in areas that have a high risk

The strategy was determined by matching the area's internal and external conditions (SWOT). Based on the SWOT matrix above, four development strategies, including the SO strategy, namely: strategies that use strengths to take advantage of opportunities, the ST strategy is strategies that use strength to overcome threats,

the WO strategy isstrategies that minimize weaknesses to take advantage of opportunities, and the WT strategy strategies that minimize weaknesses and avoid threats (Rangkuti, 2008).

a. SO (Strength-Opportunity) Strategy
   With the combination of existing strengths and opportunities, it is necessary to develop the potential of existing natural resources in new economic sectors other than mining, such as tourism, and maximize existing tourist attractions by maximizing opportunities from visits to tourist attractions around the area. It is essential to develop transportation facilities to support the development of tourism activities. Study (Islamic & Umiyati, 2020) in the former mining area, and become a tourist attraction in the Breksi Cliff, Yogyakarta, can be used as a reference for the conversion of ex-mining land with good management. As a result, from the economic aspect, there are excellent job and business opportunities, increased community income, community-based management, and accelerated infrastructure development. Meanwhile, the social aspect is the emergence of new livelihood structures in the tourism sector.
b. WO (Weakness-Opportunity) Strategy
   With a combination of existing weaknesses and opportunities, the strategy needed is the conversion of ex-mining C excavated lands to productive economic activities that pay attention to the environment and the provision of supporting facilities to maximize the area's attractiveness. Study (Kurniawan, 2013) related to the eco-friendly community mine reclamation model located in the Green Valley. This research is one of the locations of ex-mining land in the Ijobalit area, which is a model for reclamation that is environmentally sound and provides benefits to the surrounding community. In its development, the design of the new reclamation model made the former pumice mining area into a motocross arena as an alternative to development.
c. ST Strategy (Stregth-Threat)
   By using force and facing challenges, it is necessary to control land use by considering the area's sustainability to minimize uncontrolled development. A study (As'ari, Mulyanie, & Rohmat, 2019) related to zoning of post-sand mining land use on the coast of Cipatujah is one of the benchmarks for implementing this strategy. The study classified the area into three main zones based on the characteristics of community activities and the potential of each post-iron sand mining area. The research shows that the post-iron pair mining land reclamation into three zones: Zone I: a zone for *Vanna Mei* shrimp cultivation; zone II: Tourism Zone; and Zone III: a conservation area zone.
d. WT Strategy (Weakness-Threat)
   By anticipating weaknesses and avoiding challenges, it is necessary to provide assistance strategies to the community regarding environmental sustainability and improvement of existing environmental conditions, as well as mitigation efforts related to disasters that may arise due to environmental degradation. Study (Hilda, 2020) illustrates that assistance to the community is critical to changing perspectives for environmental sustainability. The research shows that the policy of closing mining land and developing tourism innovation through the transfer of functions at Breksi Cliff initially caused problems in the community. The transition period is the most challenging. This research is related to changing perspectives and behavior. So it requires all parties' involvement and the community's participation.

3.4 Development Concept

This area concept to identify regional potentials and problems. In addition, the identification of regional potentials and problems does not only include current concerns. Nevertheless, also potential problems that will arise in the future. Identifying these potentials and problems requires communication between the planner and the community who will be affected by the plan (Sirait, 2009).

Ex-excavation area C aims to increase environmental quality with innovative approaches, pay attention to natural diversity, minimize waste and waste (zero-waste), and refreshments. The concept formulated aims to

strengthen economic values for sustainability through responsible investment and empowering local communities while simultaneously exploring and increasing the potential or opportunities of the agricultural sector to encourage sustainable tourism. Based on this identification, there are four critical values in the concept of developing ex-excavated area C, namely environmental sustainability (ecology), economy (economy), community (community), and tourism (tourism).

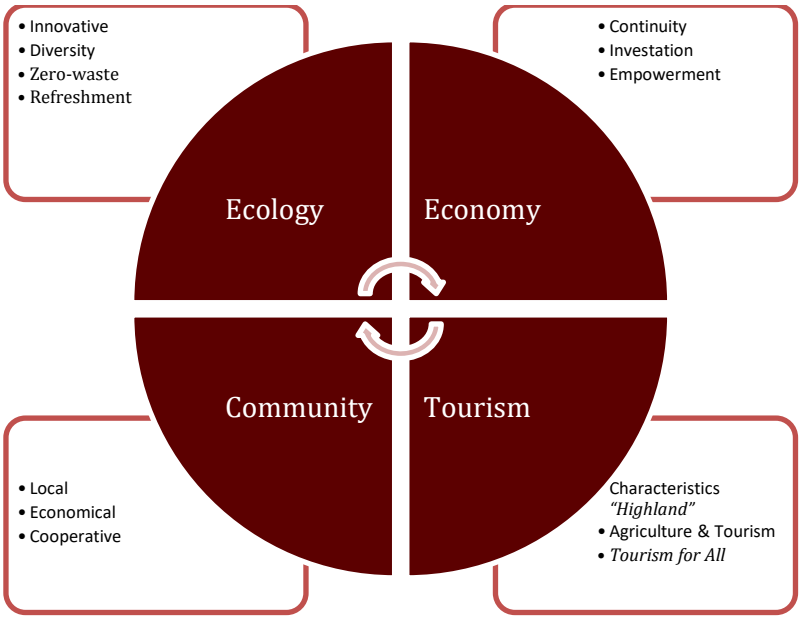

Figure 3. Development Concept

The incorporation of several values in the concept of environmental sustainability (ecology), economic sustainability (economy), community (community), and the character of tourism in highland areas (tourism) is embodied in the concept of Eco-community Highland Tourism. as a concept in which the aspects aimed at developing an area with high environmental quality and human resources are encouraged through the tourism sector as a leading sector. The development model for the ex-excavated C area integrates the high tourism potential of the area with a focus on preserving and improving the quality of natural resources and the environment, as well as with the local community.

The Eco-community Highland Tourism concept is a solution for regional development based on regional strategic issues. This concept is also one of the development models for achieving a more sustainable area. The utilization and conversion of land can be directed at the productive economic sector to replace mining. The full potential development encourages alternative land management on other ex-mining C excavated lands.

In addition, tourist attraction objects that develop at several points need to be encouraged for their development potential as a strong tourist attraction and support and complement each other in this area. Optimizing the potential of the positive impact of the corridor road construction plan on the region, not only facilitating connectivity but also generating new economic zones and the potential for the emergence of local brands. Regional development needs to optimize land functions to be sustainable and efficient (Lutfi, 2007).

In addition, the concept of developing this area is emphasized through the proximity of the planning site to other tourist attractions and making the area accessible between points and affordable in terms of distance and road infrastructure or high proximity. Proximity can be interpreted as affordability from one place to another (Talen, 2009) The proximity concept is to create an area that is accessible between points and reasonable distances and road infrastructure to increase the value and potential of tourist visits. The following figure shows the principle of high proximity in the regional development concept.

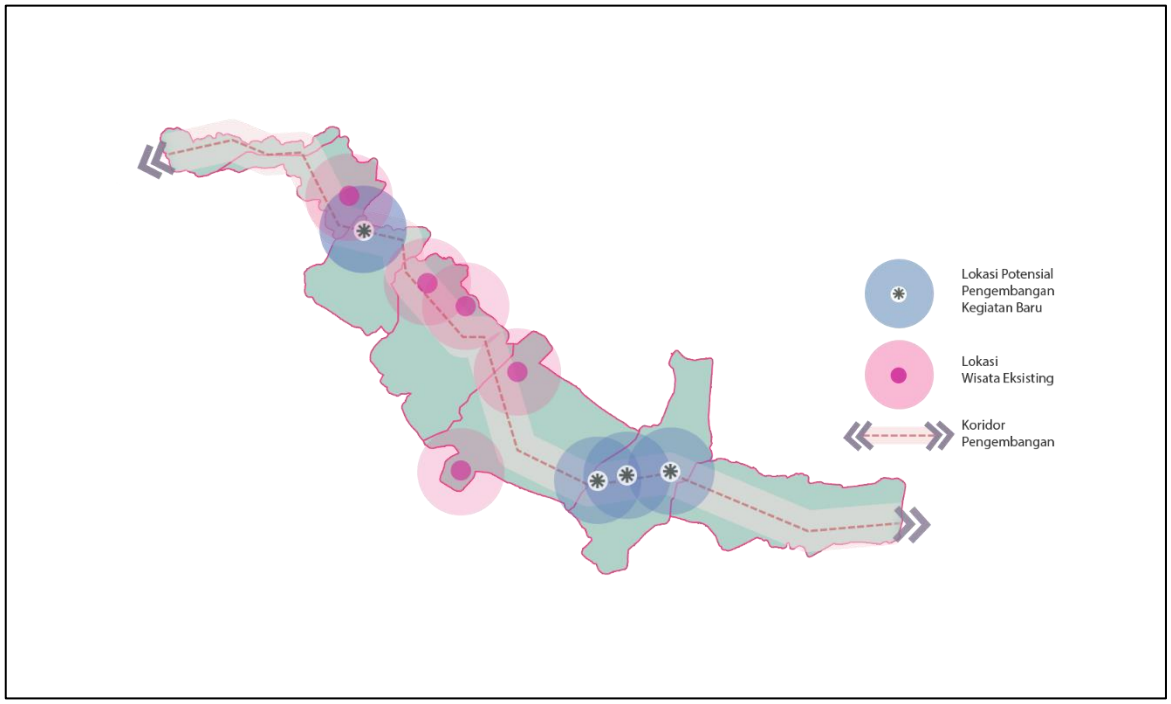

Figure 4. High Proximity Principle

Development is also on the principle of seeking balance and sustainability of natural ecosystems by maintaining green space and existing agricultural activities in the area (preserve nature and agriculture sustainability). This principle is a step to seeking balance and sustainability of natural ecosystems and maintaining green space and agricultural activities in the area. The phenomenon of climate change and the importance of environmental conservation are problems that need adaptation to regional development. It has been proven that the air temperature under trees is lower than in open areas (Zhou, Huang, & Cadenasso, 2011). The following image shows the regional development concept's principle of preserving nature and agriculture sustainability.

Figure 5. Preserve Nature and Agriculture Sustainability Principle

Regional development planning is an accumulation of economic development that sees opportunities and supply side, namely from the ability or potential of the region to develop, and in terms of demand as an opportunity (demand side - market opportunity) to develop (Harun, 2010).

Regional development needs to create a variety of activities in the area (various activities). This principle so that the activities created to make the planning area have a market with a more inclusive reach. Thus, the diversity of activities at the points of regional development is needed to encourage the development of regional attractiveness, both existing and potential. The following figure shows the principles of various activities in the regional development concept.

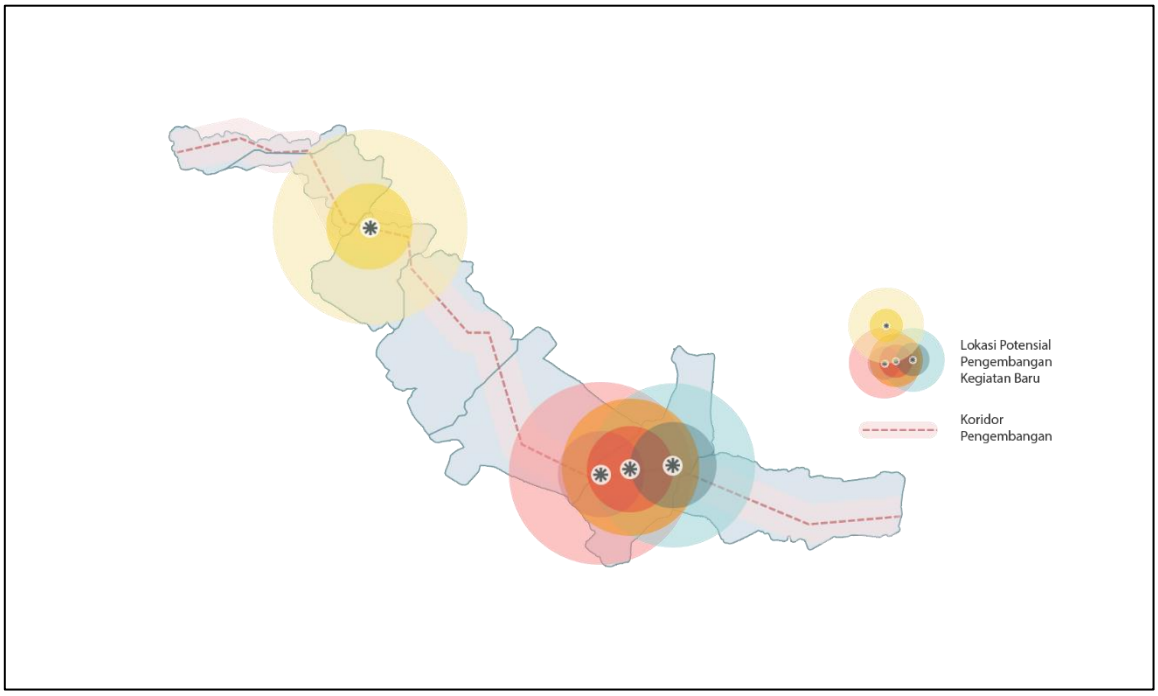

Figure 6. Various Activities Principle

Regional development is one of the regional or regional development efforts and resources (natural, human, artificial, and technology) in an optimal, efficient, and effective manner. Regional development is an effort to develop and improve the interdependence and interaction between the economic system, society, environment, and natural resources. Regional development is carried out by driving economic activities and accumulating certain investment activities that can trigger sustainable development (Soedarso, 2001).

Thus, regional development needs to create a diversity of economic activities that are mutually supportive and integrated with a management system or involvement by the local community/community (generate economy). Thus, regional development will encourage economic growth due to guaranteed sources of raw materials and markets. Economic growth will result from an increase in all economic capital. Economic growth will occur due to changes in economic activity that apply yearly and experience higher growth than what can get in the last time (Sulaeman & Silvia, 2019). Figure 7 below shows the principle of generating an economy in the regional development concept.

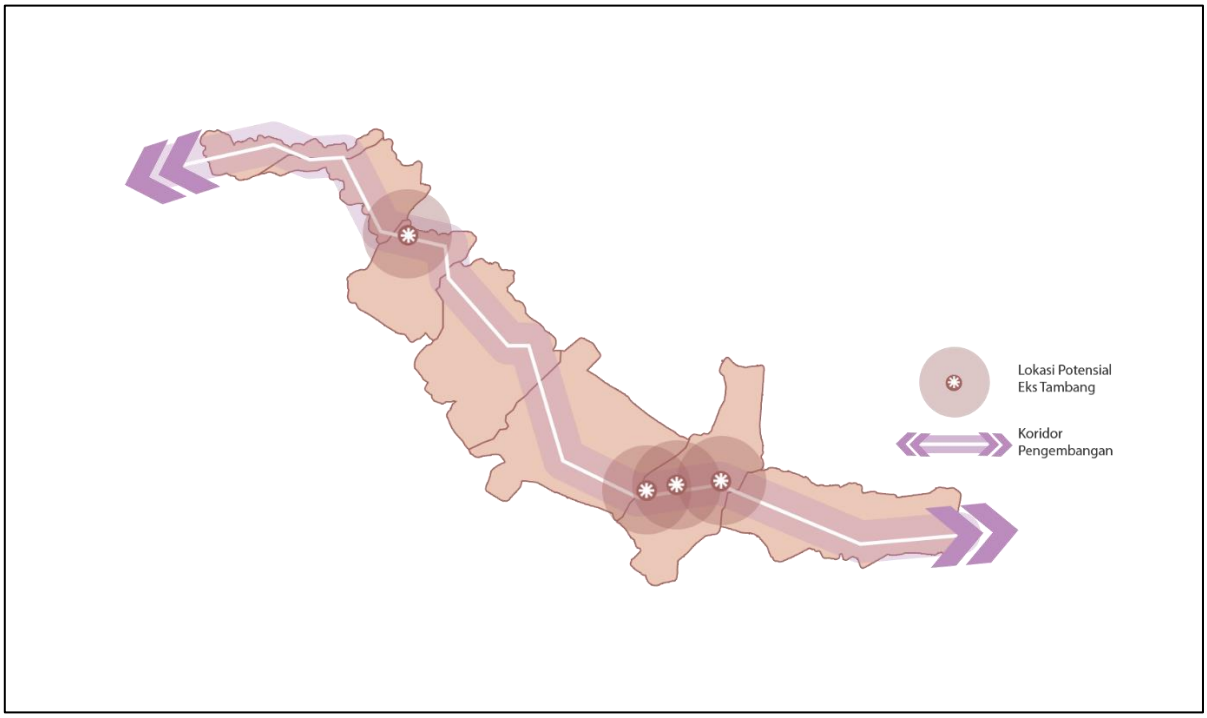

Figure 7. Generate Economy Principle

4. CONCLUSION

Based on the study results, the development of ex-mining areas of C excavation in Kertek District and Mojotengah District in Wonosobo Regency to direct the concept of Eco-community Highland Tourism. This concept aims to develop an area with high environmental quality and human resources, driven by the tourism sector as a priority. Eco-community Highland Tourism has aspects aimed at improving environmental quality, economic sustainability, community empowerment, and tourism sector development, a typical highland agricultural sector.

The development land in the ex-mining area C can serve as a conceptual guide for alternative management of excavated C land in the context of efforts to utilize and convert mining land to other productive sectors. This research is to encourage the development of regional attractiveness and to optimize the positive impact of the strategic plan for constructing the Candiyasan-Keseneng corridor that passes through the area, considering the rapidly changing existing conditions such as developments on land and tourism support by the private sector.

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Optimization of the Underframe of the Sultan Wind Turbine V5 Using the Optimization Topology Method

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Keywords

manufacture, safety factor, sultan wind turbine, topology optimization

Abstract

Sultan wind turbine is one of the products of the New Renewable Energy Engineering Lab, Faculty of Engineering Untirta which has developed from year to year until now. To keep up with industrial developments in today's era, renewal is needed to improve and update the technology contained in the sultan wind turbine. In particular, today's optimization topologies are seen as providing the possibility to realize truly manufacturing-optimized designs through topology optimization. A topological optimization is an approach that is considered powerful in design because it contributes to designs that can save energy, materials ,and time that cannot be achieved economically using other manufacturing processes. A topological optimization, as it is often called, computer configuration of the best material over 3D space, usually represented as a grid, to satisfy or optimize physical parameters. Designers using these automated systems often seek to understand the interaction of physical constraints with the final design and their implications for other physical characteristics. Such understanding is a challenge to using a visualization approach to explore the design solution space. The essence of our new approach is to summarize an ensemble of solutions by automatically selecting a set of examples and parameterizing a design space.

1. INTRODUCTION

The manufacture of the prototype of the sultan wind turbine v.1 began in 2012 and has undergone several developments to date. then the development of the prototype of the sultan wind turbine v.2 in 2014, and the development of the prototype of the sultan wind turbine v.3 in 2015, and finally the development of the prototype of the sultan wind turbine v.4 in 2017 with several changes including the seat frame, changing the shaft, and adding fin. However, because there are still shortcomings in the sultan wind turbine v.4 prototype, it is necessary to develop it into a sultan wind turbine v.5 prototypes with a lighter mount frame but does not reduce the strength of the sultan wind turbine holder.

The process of making the underframe must go through a series of tests using an application so that the desired results are appropriate and at the simulation stage it can also be known how to optimize the frame of the Sultan Wind Turbine v5.0, because the Sultan Wind Turbine works all the time, so a frame that can withstand dynamic loads is needed. The latest design of the Sultan Wind Turbine frame is expected to have a better shape, stronger and more efficient frame structure. The holder frame on the prototype of the sultan wind turbine is a part of the turbine construction that functions to transmit the load transmitted from the upper structure to the subgrade layer. This mounting frame can support the static turbine load (the weight of the turbine and other components) (Egi, 2017). The seat framework that will be designed in this study is an improvement from the previous seat framework, which is expected to produce a simpler design (Egi, 2017). The design of this mount framework includes determining the design, calculating the safety factor, and analyzing it using computer-aided design (CAD) software (Egi, 2017). In previous research on the sultan wind turbine v4.5, the framework design used a design based on structural rules and material determination using conventional materials. Determining the choice of method in computer-aided design (CAD) design is to get a more optimal design in the use of materials but not reduce the strength of the structure (Perry et al.,

2020). One example of developments in the world of structural design is using topological optimization methods, methods that use gradient-based mathematical programming techniques such as the optimality criteria algorithm and the asymptote moving method ,or non-gradient-based algorithms such as genetic algorithms. The emergence of manufacturing additives makes design complexity no longer a problem and only a matter of the number of materials to carry out the production process (Siva Rama Krishna et al., 2017). it is a very useful method for engineers and scientists to create innovative and high-performance conceptual designs (Herrero-Pérez et al., 2022)

Making the prototype of the sultan wind turbine, there have been many developments, starting from the manufacture of the prototype of the sultan wind turbine v.1 which was made in 2012 ,and continued in the manufacture of the prototype of the sultan wind turbine v.2 in 2014. Thus the prototype of the sultan wind turbine is developed again. in 2015 became the prototype of the sultan wind turbine v.3. In the testing phase for the prototype of the sultan wind turbine v.3, there are several that must be developed to become the prototype of the sultan wind turbine v.4, including changes to the seat frame, changes to the shaft, and the addition of fins as a determinant of wind direction. In Cilegon where this research was conducted, not many have tried to capture the potential of wind energy, to be used as alternative renewable energy, which incidentally is close to the offshore Cilegon which has good wind potential to be used as an alternative energy source. So that in practice a blade that has superior performance is needed in capturing wind energy that is by the characteristics of the city of Cilegon. As for the characteristics of the wind, namely, wind that changes frequently, frequent occurrence of turbulence, and speed increases with altitude (energy is proportional to the power of three multiples), the actual potential is determined by the distribution of wind speed (topography) of the location. Meanwhile, the wind speed in the Cilegon area is 2 m/s – 4 m/s (Sippa, 2019). The wind turbine which is now located on the top floor of the Sultan Ageng Tirtayasa University Rectorate Building can still be developed further and find solutions to the problems that exist in the sultan wind turbine v4, including the framework that has begun to be corrosive and a lighter frame is needed based on previous research (Egi, 2017). The purpose of this study was to design the underframe of the Sultan Wind Turbine V5.0 to obtain a more stable and durable frame design and a stronger and lighter pedestal.

1.1 Topology Optimization

Generative design is a term that encompasses the various types of technologies involved in modeling these progressive types of products. These technologies include topology optimization, biomimicry, experimental design methods ,and lattice structure creation. Biomimicry imitates patterns or processes from nature which are then applied in the industry (Pollak et al., 2020). Three main parts in optimization are topology optimization, size optimization, and shape optimization(Pilagatti et al., 2021). The combination of topology optimization and additive manufacturing provides more creative space for the design and manufacture of various components(Kang et al., 2021).The development of the optimization topology was initially shown for 2D problems, then gradually it can be used for 3D integrated with CAD (Cuillière et al., 2018) Compared to conventional manufacturing, process topology optimization gives users the freedom to produce very complex geometries and material compositions(Wang et al., 2021). The optimization topology shows the effectiveness of the proposed optimization algorithm to get a structure with maximum damping or stiffness(Huang et al., 2015). Conventional manufacturing strategies have evolved to realize design goals for a wide variety of applications, but topology optimization is and will continue to have a major impact on design and manufacturing(Blakey-Milner et al., 2021). Little by little, topology optimization, which is a high-cost and difficult-to-obtain method, has developed and is available in the form of applications for research fields, such as structure optimization.(Roque et al., 2021)

Topology optimization is a mathematical method that optimizes the layout of materials within a given design space, for a set of loads, boundary conditions, and constraints with the aim of maximizing system performance. The optimization topology method is directly extended to a robust formulation to achieve an eroded, intermediate, and widened design topology so that the design is resistant to possible manufacturing errors (Huang & Li, 2022). Topology optimization is also a shape optimization method that determines the

optimal structure in the design domain for high structural efficiency (Kim, 2020). Topology optimization differs from shape optimization and size optimization in the sense that the design can achieve any shape within the design space, instead of handling predefined configurations. The conventional optimization topology formulation uses the finite element method (FEM) to evaluate the design performance. The design is optimized using gradient-based mathematical programming techniques such as optimality criteria algorithms and asymptote moving methods or non-gradient-based algorithms such as genetic algorithms (Perry et al., 2020). In this case, structural optimization is an application of topology optimization with the to aim the optimal distribution of materials according to the demands of a structure (Kalantre et al., 2018).

Figure 1. Topology result

The optimization method used in topology optimization uses Optistruct Altair software. The topology optimization of the underframe design is carried out because the shape is a structure and topology optimization results in a large enough mass reduction (Suryo et al., 2021). Altair Inspire's topology optimization technology makes it possible to get the exact shape of the product according to the specified load and constraints. However, due to the specifications of the optimization algorithm, it may be necessary to manually increase the amount of material in the part to make the optimized assembly more technologically advanced (Dolmatov & Kolesnikov, 2020). Process flow for topology in Altair Inspire: (Nandanwar et al., 2021)

The first step is to develop a CAD model from the required parts and generate an sldprt format file, then open Altair Inspire and import the Solidworks file in it, dividing the model into 2 parts design space and non-design space, for simulation, such as support, force, pressure or moments , etc. Material properties are also selected for the section, after all the above steps are completed the icon for topology optimization is selected. Now there are 2 goals of minimizing weight or maximizing stiffness (for the selected weight percentage, for the underframe, the maximum stiffness is chosen for a certain percentage of the weight, after the simulation is complete, presented with a rough surface optimized for the topology, finally making the results smoother using the features called *polynurbs* which smoothen the surface to improve mechanical properties and make it manufacturable. Topological optimization finds initial structural configurations that meet predetermined criteria based on finite element analysis (FEA) and sometimes provide completely new and innovative designs. (Yan et al., 2022) With the structure already integrated, production exhibits optimal mechanical strength and encourages design unification.(Meena et al., 2021)

1.2 Factor of Safety

The factor of safety is obtained using the thumb method, the factor of safety can be quickly estimated using a variation of five measures (Ullman, 2017). The Factor of Safety (FoS) is how much the system can withstand more than the expected or actual load. The Factor of Safety also known as a factor of safety is often calculated using the ratio of the ultimate load to the allowable load for a model or structural design in constructions such as bridges and buildings. The factor of safety is basically used to ensure the structural design does not occur unexpected failure or deformation or defects. The smaller the Safety Factor, the higher the chance for the design to fail. Resulting in uneconomical and non-functional designs. As for the higher Safety Factor, the components will be much more expensive resulting in higher design costs (Maria, 2016).

FS=(Fs material)(Fs stress)(Fs geometry)(Fs analysisfailure)(Fs reliability) (1)

Estimated Contribution to Material, FS material

• FS = 1.0 if material properties are known. Experimentally obtained from specimen testing.

• FS = 1.1 if material properties are known from manuals or fabrication values.

• FS = 1.2 – 1.4 if the material property is not known.

Estimated contribution of stress due to overload, FS stress

• FS = 1.0 – 1.1 if the load is limited to static or fluctuating loads. If an overload or shock load and if using accurate analytical methods.

• FS = 1.2 – 1.3 if the normal force is limited to a certain condition with an increase of 20%-50% and the stress analysis method may produce an error below 50%.

• FS = 1.4 – 1.7 if the load is unknown or the stress analysis method has uncertain accuracy.

Approximate contribution to geometry, FS geometry

• FS = 1.0 if the production tolerance is high and guaranteed.

• FS = 1.0 if the tolerance of the average production yield.

• FS = 1.1 – 1.2 if the product dimension is less important.

Estimated contribution to failure analysis FS failure analysis

• FS = 1.0 – 1.1 if the failure analysis comes from stress types such as uniaxial stress or multiaxial static stress or full multiaxial fatigue stress.

• FS = 1.2 if the stress analysis used is a simple theoretical area of multiaxial, full alternating stress, and uniaxial average stress.

• FS = 1.3 – 1.5 if the failure analysis is static or does not change as in a typical breakdown or multiaxial average stress.

Estimated contribution to reliability, FS reliability

• FS = 1.1 if a component does not require high the reliability.

• FS = 1.2 – 1.3 if the reliability at the average price is 92% - 98%.

• FS = 1.4 – 1.6 if the required high reliability is more than 99%.

To determine the value of the safety factor based on the maximum stress and working stress are: (Ullman, 2017)

$$SF = \max/\sigma work \quad \text{.....(2)}$$

Information :

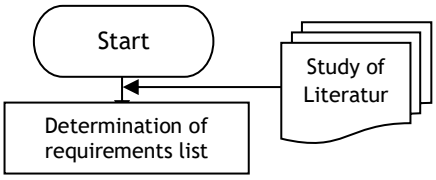
SF: Safety factor

max: Maximum stress (N/mm2)

work: Working Voltage (N/mm2)

2. METHODS

The following are the stages of the research used as shown in Figure 2. Flowchart of the optimization research under the sultan wind turbine v5 frame using an optimization topology method.



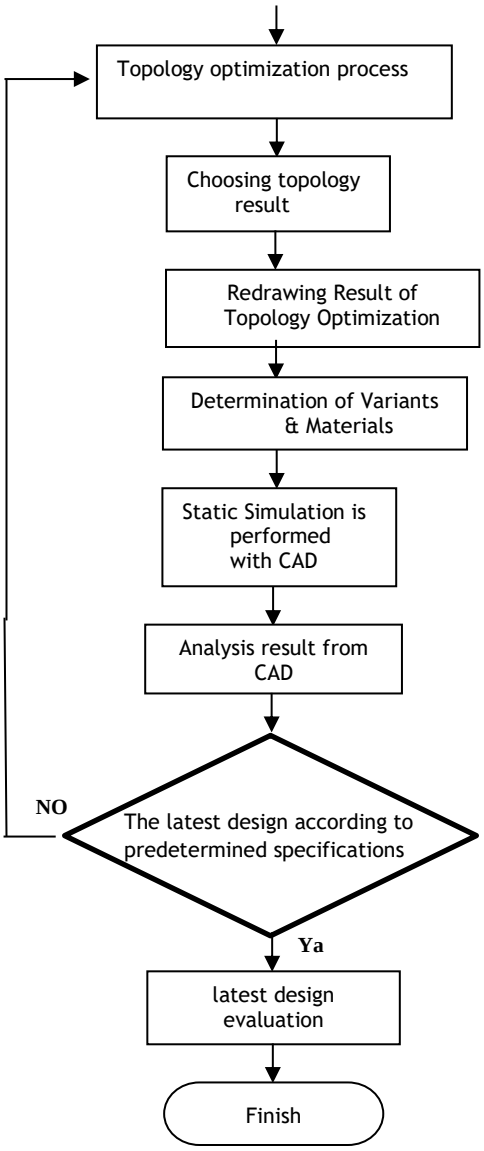


Figure 2. Research methods

The explanation of the research method so that the flow chart above can be easily understood.

1. Study of Literatur

The first stage of this research is collecting information sources, reading, and understanding them. The sources come from various journals, theses, and also articles on the internet. The manufacture of the prototype of the sultan wind turbine v.1 began in 2012 and has undergone several developments to date. then the development of the prototype of the sultan wind turbine v.2 in 2014, the development of the prototype of the sultan wind turbine v.3 in 2015, and finally the development of the prototype of the sultan wind turbine v.4 in 2017 with several changes including the seat frame, changing the shaft, and adding fin. However, because there are still shortcomings in the sultan wind turbine v.4 prototype, it is necessary to develop it into a sultan wind turbine v.5 prototype with a lighter mount frame but does not reduce the strength of the sultan wind turbine holder.

For writing this report, the sources are mentioned in the bibliography section.

2. Determination of Requirement List

At this stage, it will be explained what are the requirements for the design of the Sultan Wind Turbine underframe. This stage explains and defines tasks by describing tasks in a list of requirements

containing constraints in the form of requests and wishes. The requirement list used is the one from Alexander and Beus. Based on research conducted by Ljerka Beus-Dukic and Ian Alexander in 2008, this approach is more realistic and pragmatic for requirements lists by using a combination of requirements elements and discovery context. The results achieved from the research of Ljerka Beus-Dukic and Ian Alexander are positive that this approach will help turn an unclear problem into a clear problem such as Required Functionality (Use Case Diagram), Application domain information structure (Domain Model), and List of all requirements functional and Indicate its priority. The requirements list fulfills adequacy, correctness, coverage, readability, and consistency (Alexander & Beus-Dukic, 2008). Limitations of demand and desire themself are internal, i.e. limits are created by the author or external, namely restrictions obtained from users (consumers), so that some requirements cannot be calculated , or determined as a cost calculation. In short, Wish is a must-have consumer expectation that the design is worth the investment, while demand is something that a product must fulfill. otherwise, the status will be rejected.

Table 1. *Requirement List* (Alexander & Beus-Dukic, 2009)

Requirement List		Explanation	*Wish* = W Demand = D
Functional	Work System	Capable of withstanding the forces caused by the components above the wind turbine underframe	D
Geometry	Framework	Optimal and able to withstand static loads and has better strength than the previous version	D
Material	Framework Material	The type of material is easy to get	W
		Able to withstand a force of 886.0768 N and 1330.71 N	D
		Corrossion resistence	W
Maintenance	Maintenance	Easy maintenance	W
Output	Safety	Safe in simulation test (meet or greater than safety factor)	D

3. Topology Optimization Process

The topology process for optimizing the design of the subframe structure uses Altair 2019.4 Before performing topology optimization, several data must be prepared, namely Material properties, loading data, and Design space.Pemilihan Hasil Topologi. Selecting the optimization topology results from various experiments that have been carried out with the results of the analysis of the original shape of the optimization topology results using CAD static simulations in this case using Altair Inspire

4. Choosing Result of Topology Optimization
5. Redrawing Result of Topology Optimization

Redraw the results of the optimization topology because the results of the optimization topology are not in the form of blocks and have varied dimensions. Then the design will be made using a truss method. Truss is a framework that involves parts assembled into an object (Koirala et al., 2021). The ideal link between additive manufacturing and structural optimization is a key element in today's product development. On the one hand, models are manufactured with the addition of thousands of layers using additive manufacturing. It offers designers great geometric flexibility, at no extra cost, compared to traditional manufacturing. Additive manufacturing includes many technologies such as 3D printing, rapid prototyping, and direct digital manufacturing. On the other hand, structural optimization reduces material usage, shortens design cycles, and improves product quality. Structural optimization can be implemented. (Tyflopoulos et al., 2018)

6. Determination of Variants and Materials

Choose the best variant of the shape from the results of redrawing and the selection of materials that are stronger and easier to obtain.

7. Static Simulation with Software

The results of the selection of variants and materials are simulated using CAD

8. Analysis of Simulation Results on CAD
   Get results from static simulations in the form of voltage and safety factor data
9. Latest Design According to Specified Specifications
   Get results that match the specified requirements list
10. Evaluation of Latest Design Results
    Collect the data that has been obtained and define dimensions and material information

3. DISCUSSION

Topology Optimization Simulation

Topology optimization is a mathematical method that optimizes the layout of materials within a given design space, for a set of loads, boundary conditions, and constraints with the aim of maximizing system performance. The simulation is performed using computer-aided design (CAD) software which is capable of performing shape optimization and size optimization analysis in the sense that the design can achieve any shape within the design space, instead of handling predefined configurations. The application used to perform the topology optimization process using the Altair Inspire 2019.4.From the results obtained from the results of topology optimization with two loading directions. It is assumed that the solid results follow the existing shape, and the shape below is designed with the assumption that the load moves from all directions. And redrawing the design using an existing profile.

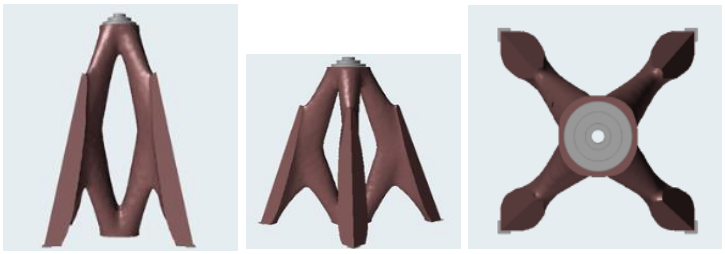
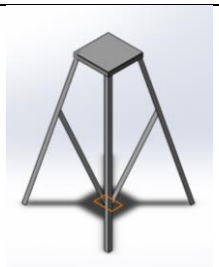
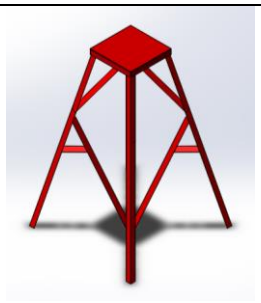


Figure 3. Topology Optimization result

From the simulation results and after redrawing, the results are similar to the shape of the simulation results. And added bracing to increase the strength of the frame structure.

Table2. Redrawing result

Model	Visualization	
Without Bracing		

With Bracing		

3.1 Under Framework Simulation

Under frame is a part of the construction that serves to transmit the load transmitted from the upper structure to the soil layer. The lower mount frame can to support the compressive force caused by the weight of the components above it and can to withstand the force caused by the wind. The following are some simulation results based on the materials used, which are shown in the image below. From the simulation results, the following results are obtained:

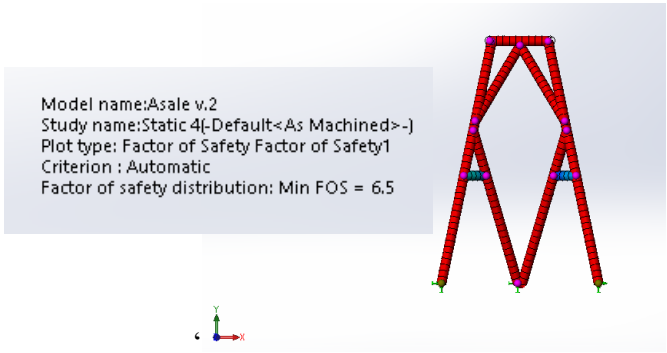


figure 4. Result Factor Of Safety

U To make the design more stable, from the results of redrawing the results of the optimization topology, braces are added to the design. And obtained the value of the safety factor of 16. Furthermore, the Contribution Estimated Analysis is carried out in terms of the aspects carried out in the simulation.

$$FS=(Fs_{material})(Fs_{stress})(Fs_{geometri})(Fs_{fatigueanalysis})(Fs_{reliability}) \quad (3)$$

so that,

1. Estimated contribution for Material, ie Fs Material = 1.1

Because the specified material properties are known from the manual and the fabrication value.

2. Approximate contribution to Stress, i.e. Stress Fs = 1.1

Because the loading carried out during the simulation is a static loading, it is also by the research scope or problem constraints.

3. Estimated contribution to Geometry, i.e. Geometry Fs = 1.0

Because, the tolerance given when designing the Frame Construction in Computer-Aided Design (CAD) Software is the average tolerance value, which is +- 0.01mm

4. Estimated contribution to failure analysis, ie Fs Failure Analysis = 1.2

Because the stresses applied during the simulation are on the theoretical area (surface) of a simple frame, such as axial stress, multiaxial stress, and uniaxial average stress.

5. Estimated contribution to reliability (the ability of the structure to withstand loads), i.e. Reliability Fs = 1.3

Because the reliability determined during the simulation ranges from an average value of 92-98% (according to the force values and equations used)

So, the minimum Factor of Safety that needs to be achieved is:

FS = (1,1).(1,1).(1,0).(1,2).(1,3)
FS = 1,8876

It can be concluded that, based on the simulation results in the simulation, the FS value is 2, where the minimum FS based on the above equation is 1.8876. It can be concluded :

FS simulation > FS manual = safe

Then, **6.5 > 1,8876 = safe**

4. CONCLUSION

Based on the research that has been done, it can be concluded that:

1. From the results obtained, the safety factor of 6.5 from the static simulation results on the CAD is greater than the Ullman equation which is 1.887, then the design of the Sultan Wind Turbine underframe is declared safe.
2. The selected topology results are with five force directions as shown in Figure 2.
3. For further research, it is better to use a more sophisticated CAD application to change the results of the optimization topology method into a design form that is commonly found in everyday life.

5. THANK-YOU NOTE

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Fire Vulnerability Assessment using Multicriteria Analysis in Makassar City

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Keywords

Multicriteria Analysis; Fire; Vulnerability; Makassar; GIS

Abstract

The safety aspect, especially the fire disaster, is essential for Makassar City because of its role as a metropolitan city and a center of activity in the Eastern Indonesia Region. The dense population and activities make Makassar City vulnerable to fires. A vulnerability assessment can assist in urban disaster management, especially in highlighting areas of fire disaster mitigation. Based on this urgency, this study aims to identify fire-prone areas in Makassar City. This study examines the fire vulnerability of Makassar City from population density, building density, frequency of previous fire events, fire fires, distance to the availability of clean water, and dangerous buildings. Fire susceptibility criteria are based on stakeholder assessments involving disaster experts, city planners, and firefighters through the Analytical Hierarchy Process. Spatial assessment using multi-criteria analysis through the Simple Additive Weighting method, which is integrated with the Geographic Information System to allow spatial weighting. The study results show that the western and northern parts of Makassar City are very prone to fires. This area is an early development area for Makassar City, characterized by a dense population and buildings with various activities.

1. INTRODUCTION

Makassar City, the largest metropolitan city in the Eastern Indonesia Region, accommodates various urban activities every second. The high population due to the influence of urbanization in Makassar City demands an increase in urban facilities services. Judging from its vitality, Makassar City should be able to accommodate various urban activities with a sense of security and comfort to increase the productivity of city residents. However, like other cities in Indonesia, Makassar City is also inseparable from urban problems, one of which is fire. Fire is a disaster that is difficult to predict when it will occur, and the risk of the amount of loss caused is quite considerable, so responsive conditions are needed to overcome it. In addition, Makassar City, with its densely populated condition, is prone to and prone to fires.

The massive development in Makassar City has resulted in changes in physical, social, environmental, and other aspects of Makassar City, which indirectly have implications for the city's ability to perceive environmental changes and disasters that may occur. Almost every month, tourism in Makassar City experiences fires. Based on data from the Makassar City BNPB fire incident report, the number of incidents in Makassar City in 2020 was recorded at 105 cases. From 2015 to 2020, the number of fire incidents tends to fluctuate.

Disaster vulnerability is a characteristic of an area over a certain period to reduce the ability to respond to specific adverse impacts (Hizbaron, 2021). Fire vulnerability has threats from natural and non-natural factors and social factors. Fire susceptibility refers to the physical aspect of the occurrence of fire. There are nine essential criteria in fire-prone areas: land use, building density, number and location of fires, air sources, hydrants, building materials, electricity networks, and disaster response time (Dahlia, 2018). Several other factors, such as road width, building layout, and internal activities by Irawan and Faiz (2021). In his research, Widiyantoro (2016) uses vulnerability variables such as population density, building density, building size, the distance between buildings and their construction, road width, and distance to fire. From a different

perspective, Chisty and Rahman (2020) review fire events through community awareness and readiness and their ability to deal with fires to property and connections between communities. Mustika (2018) also mentions the building on a micro-scale. Factors that influence fire risk, especially in high-rise buildings, are means of protection, accessibility of fire cars, life safety facilities, and building fire safety. The previous factors are factors or variables considered influential in the level of fire risk. Several general factors can be drawn, such as population density, building density, existing fire services, previous fires, distance to air sources, and hazardous buildings. To be clear, the following is a table of literature reviews of previous studies that are relevant to the topic:

Table 1. Relevant Previous Research

Author, Year, and Title	Research Result
Widiyantoro, B. A (2016). Analisis Tingkat Resiko Bencana Kebakaran di Kecamatan Mariso Kota Makassar Berbasis Sistem Informasi Gegrafis (SIG)	This study assesses the Mariso District disaster in 2016 using the weighting method. This study revealed that the fire risk occurred in a controlled area, with no fire protection equipment and low accessibility at the location.
Dahlia. S, et al (2018). Pemetaan Zonasi Daerah Rawan Kebakaran mmenggunakan Citra Quickbird di Kecamatan Tambora Provinsi DKI Jakarta	This study discusses fire hazard mapping using quickbird imagery in Tambora District, DKI Jakarta. The approach taken is natural and social science. The variables considered are land use, building density, road width, rivers, public perception of the frequency of fires, historical events, and mitigation efforts. This study reveals that fire-prone areas tend to occur in areas with high fire frequency, an inadequate number of hydrants, unsafe electricity networks, narrow road access, and dominated by semi-permanent buildings.
Taridala. S, et al (2017). Model Penilaian Risiko Kebakaran Perkotaan dengan Sistem Pakar berbasis Gis Grid-Based	This study aims to assess the risk of fire in Kendari City. The method used is to combine expert systems in grid-based spatial analysis. The results showed that the areas with a fire risk d=very high were built-up areas with densely populated areas dominated by semi-permanent buildings. High-risk areas have low accessibility and are in a hilly morphology.
Srivanit, M. (2011). Community risk assessment: spatial patterns and GIS-based model for fire risk assessment-a case study of Chiang Mai municipality	This research was conducted in Chiang Mai Municipality, and one of the objectives was to assess fire risk. The method used is MCDA (Multicriteria Decision Analysis). Factors considered include the type of building material, building height, density, population density, hazardous buildings, distance to fire sources, accessibility, distance to fire stations, hydrants, frequency of fires, and distance to water sources. The study results found that prone areas are in the study area. The vulnerability factor with the highest weight is the type of building material and the density of the building.
Widyatmadja, W., & Purwanto, T. H. (2013). Aplikasi Penginderaan Jauh dan Sistem Informasi Geografis untuk Pemetaan Zonasi Kerawanan Kebakaran Permukiman dengan Memanfaatkan Citra Quickbird di Kecamatan Balikpapan Selatan.	This study maps fire vulnerability using quickbird imagery with scoring and weighting in South Balikpapan. The variables considered are the availability of hydrants, water sources, and road quality. The results of the assessment accuracy reach a value of 89%, which is quite suitable for studying urban areas.
Isma, F. et al (2021). Kajian Daerah Rawan Kebakaran Kota Langsa Menggunakan Metode Weight Product (WP).	This research was conducted in Langsa City using the Weight Product method. Factors to consider are population density, built-up area, frequency of occurrence, the reach of firefighters, road ratio, and water supply. This study found that most areas have a low level of fire susceptibility with regional characteristics, namely low population density and sufficient water supply.
Wang, K., et al (2021). A POIs based method for determining spatial distribution of urban fire risk.	This research was conducted in Zhengzhoung to analyze fire vulnerability using the point of interest (POIs) by considering expert scoring through the AHP technique. This study assesses the function of the building. As a result, fire-prone areas are dominated by residential areas. The weakness of this

Author, Year, and Title	Research Result
	method is that it uses points so that considerations related to the size of the building cannot be identified.

Fire vulnerability assessment is the main foundation of efforts to prevent, mitigate, and improve preparedness for fire disasters. Several studies that use fire vulnerability assessments, namely Taridala et al. (2018), assess based on the clean air network system with fire vulnerability. Another infrastructure is the optimization of the location of the fire post (Bagir and Buchori, 2012). In addition, a fire hazard assessment is also needed for fires that are useful for transportation systems (Avdeeva, M, 2022). Fire mapping is also needed in preparing fire mitigation (Neto and Ferreira, 2020).

A city must have a fire hazard assessment based on the city's development. Studies in China on fire data reveal that the use of fire data and updating of fire data has a significant impact on reducing fires and fire consequences (Liu et al., 2022). Previously, Widiyantoro (2016) assessed sub-districts in Makassar City with a focus on the Mariso District. However, this assessment was limited to one sub-district, not comprehensive in Makassar city. In addition, this research was conducted in 2016, which is quite long compared to the massive development in Makassar City every year. So, more or less, there has been a change in the structure and pattern of space in Makassar City, which makes this research necessary to get a complete picture of fire vulnerability in Makassar City.

Reflecting on the previous and based on the urgency of the vitality of Makassar City as a metropolitan city, it is essential to do this at a depth related to fire hazards in Makassar City. Thus, this study aims to identify fire-prone areas that are expected to influence reducing fires in Makassar City.

2. METHODS

The data used are primary and secondary data. Primary data consists of expert preferences for the importance of fire susceptibility criteria. Secondary data includes spatial data on administrative boundaries, land use, frequency of fire occurrences, building functions, and population. Primary data were obtained through interviews and questionnaires by two experts including academics in the field of spatial planning for residential areas, urban planners and government, namely the fire department. At the same time, secondary data was obtained through literature studies and data collection agencies.

Previous research has explored many fire assessments with various analytical methods and techniques. Some of them use methods and techniques such as Point of Interest (POIs), Computational Fluid Dynamics (CFD), Fire Risk Analysis Method for Engineering through Building Information Modeling (BIM), Dynamic Risk Assessment (DRA), and AHP using expert choice applications (Wang, L. et al., 2021; Zhang, F. et al., 2022; Wang, L. et al., 2021; Feng, J. R. et al., 2022; Taridala, S. et al., 2018). The variety of methods, analytical techniques, and tools that can be used to analyze fire assessments facilitate fire assessments and affect the accuracy of the assessment. The determination of the method used, of course, is based on the conditions and character of the area. Socio-cultural differences and space activities will form differences in the tendency of different fire patterns. Therefore, the determination of analytical methods and techniques was chosen by involving the opinions of experts who certainly understand the character of the study area. The method considered appropriate is the analytical hierarchy process which involves experts in determining the priority weight of the fire susceptibility variable. In addition, the spatial assessment is carried out using the simple additive weighting method spatially using the QGIS 3.16 application to quantify and visualize the assessment.

In stages, the fire hazard assessment is divided into two stages: determining the criteria and level of importance using the analytical hierarchy process and spatial analysis of fire hazard using the simple additive weighting method. The analytical hierarchy process includes four stages: problem decomposition, comparative assessment, value synthesis, and consistency testing (Saaty, 2008). The assessment uses pairwise comparisons through a number scale that shows how much more critical or dominant an element value is than another. The

results will eventually be validated with a logical consistency test. Calculations are valid and logical if the consistency ratio does not exceed 10% or 0.1 logical consistency formula as below.

$$CI = \frac{\lambda \max - n}{n-1} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

Where:
CI = Consistency Index
RI = Ratio Index
CR = Consistency Ratio

After obtaining the weights of each criterion of importance, proceed with spatial analysis using the Simple Addititve Method (SAW). The SAW method is a multi-criteria analysis method known as weighted addition which was first written by Churchman and Ackoff (1945). Previously, the SAW method has been applied by several researchers for disaster vulnerability assessment as done by Setyani and Saputra (2016). The stages are determining the criteria, determining the suitability rating for each criterion, making a normalized decision matrix, then adding up the values of each weighted criterion (Chackraborty and Yeh., 2012., and MacCrimmon, 1968). Normalization can be done using the formula adapted by Chackraborty and Yeh (2012) and Vafaei et al. (2022).

$$r_{ij} = \frac{x_{ij}}{x_j^{max}} \quad (3)$$

Where:
r_{ij} = Normalised ratings
X_{ij} = Performance ratings of j
X_j^{max} = Maximum performance rating among alternatives for j attribute

The normalized score then continued by calculating the total value of each criterion on the alternative using the provisions adopted by Chackraborty and Yeh (2012) and Vafaei et al. (2022).

$$V_{ij} = \sum_{i=1}^{n} w_j r_{ij} \quad (4)$$

Where:
V_i = Preference value of decision alternative of i
w_j = The normalized values of j
r_{ij} = Weight of j

3. RESULT AND DISCUSSION

3.1 Fire vulnerability criteria

Determination of criteria is done through literature study and policy review related to fire hazards. Literature review and policy rules used are the Decree of the State Minister of Public Works No.11/KPTS/2000

of 2000, Regulation of the Minister of Public Works number 20/PRT/M/2009 of 2009, Hazardous building standards by the National Fire Protection Association (NFPA), Dahlia (2018), Taridala (2018), Widiyantoro (2016), and Irawan and Faiz (2021). The criteria used for this study consisted of six criteria, namely population density, building density, fire extinguisher range, distance to water availability, dangerous buildings, and frequency of fire occurrences. The results of the weight calculation for each criterion can be seen in Table 2 below:

Table 2. Weight of Importance of Fire Vulnerability Criteria

Criteria	Weight
Densely populated area	0.29
Congested area	0.25
Dangerous building	0.22
Areas of high fire frequency	0.12
Far from the availability of water sources	0.06
Far from the reach of fire services	0.06

Based on the analysis of the importance of the criteria, it was found that densely populated areas are the criteria with the highest weight of fire hazard of 0.29 or 29%. The results show that the lowest criteria have the same weight between the availability of water sources and the range of fire services, with a weight of 0.06. Densely populated areas are considered to have the highest level of importance or, in other words, criteria that significantly impact fire susceptibility because they take into account the material and life losses that may occur. Apart from being densely populated, it is also densely populated. The tendency is that the fire will enlarge when it is in a dense area and spread more quickly if it is densely built with semi-permanent materials. Areas with high building density are usually in the middle of urban areas. They are slum areas, so most building materials used are flammable. In addition to building materials, several buildings are vulnerable due to the functions and activities in these buildings. Areas with dangerous buildings such as warehouses, flour factories, plastic factories, and others are counted as vulnerable areas because they are at high risk in the event of a fire. Furthermore, in areas with a high frequency of fires, based on theory, there is a tendency for areas that frequently experience fires to experience repeated fires, although not absolutely. Other criteria, such as the distance from water availability and the range of fire fighting services, are considered the lowest priority because they consider the condition of Makassar City, which has several reservoirs, rivers, and other water sources in urban areas. In addition, the existing infrastructure also makes it possible to store water and retrieve water reasonably quickly.

3.2 Fire vulnerability spatial analysis

fire hazard assessment is carried out for the entire Makassar City area, except for the islands. The research area covers 14 sub-districts, as depicted in Figure. 1. The analysis was carried out using vector-based spatial analysis. According to the research area, the vulnerability assessment begins by forming a grid measuring 100 x 100 meters in a hexagonal shape. Each grid has an identification number that distinguishes it as an alternative to simple additive weighting calculations later. The formed grid follows the shape of the research location in as many as 15,694 grids. After the primary grid is formed, it is continued with an assessment of the physical condition of the land by comparing it to the fire hazard indicators. The score is a value that indicates fire susceptibility in terms of influential criteria. The higher the score/rating value on the grid against the criteria, the more prone the grid is to fire. The scores used in the calculations were obtained through a study of the literature and related regulations, as shown in Table 3.

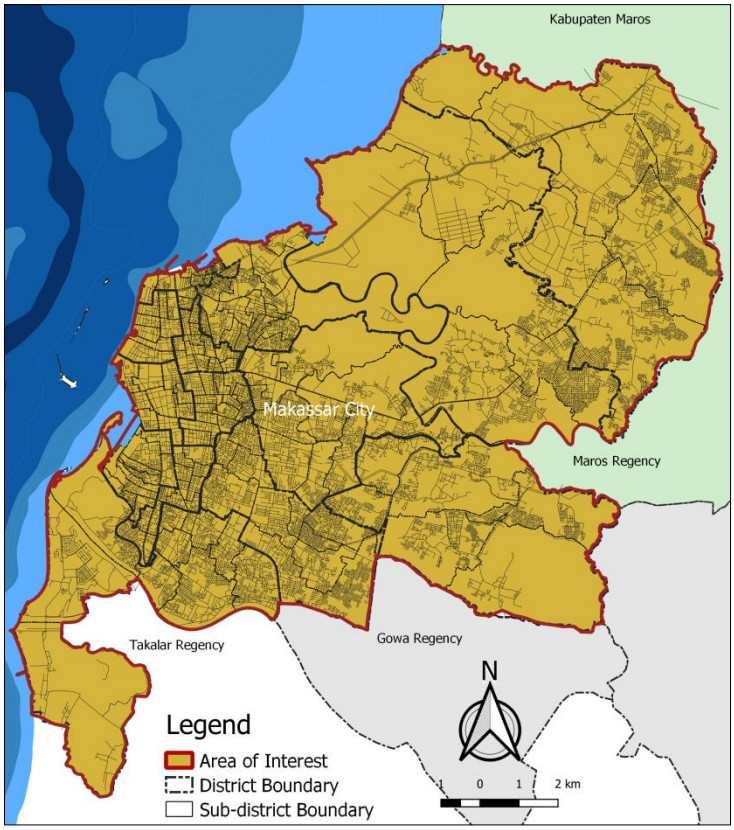

FIgure 1. Area of Interest

Table 3. Criteria Rating Value

Criteria	Indicator	Rating
Densely populated area	High population density (> 200 people/Ha)	3
	Mederate population density (151-200 people/Ha)	2
	Low population density (<150 people/Ha)	1
Building density	Very high building density (> 81 Buildings/Ha)	5
	High building density (61-80 Buildings/Ha)	4
	Moderate high building density (41-60 Buildings/Ha)	3
	Low building density (11-40 Buildings/Ha)	2
	Very low building density (< 10 Buildings/Ha)	1
Distance to water source	Distance to water source is far (> 1000 m)	3
	Distance to water source is moderate (250-1000m)	2
	Distance to water source is nearby (<250 m)	1
Firefighter's reach	Distance to fire station is far (>7,5 km)	3
	Distance to fire station is moderate (2,5-7,5 km)	2
	Distance to fire station is nearby (<2,5 km)	1
Dangerous building	Plastic warehouse and factory, flour factory,	5
	Warehouse and paper mill, rubber factory and storage, granary	4
	Printing, textile factory, agricultural equipment warehouse	3
	Parking, petrol station,	2
	Apartments, schools, fire stations, hospitals, museums, prisons, schools, offices	1
Fire frequency	Frequently Happening	3
	Rarely happening	2
	Happened	1

Based on this value, each grid is assessed according to the characteristics of the grid. The assessment results were then normalized for each criterion as in the provisions of MacCrimmon (1968) by dividing the value of the criteria by the maximum value that can be obtained on each grid for each criterion. The assessment for each criterion is carried out through spatial analysis, as shown in Figure 2. The population results, as in part (a), show that the area is marked red on the map. Furthermore, the distribution of buildings tends to be scattered in various areas in Makassar City, several dangerous buildings are close to each other, and that is a flour factory located in the Soekarno-Hatta Port Area. For the previous incident, it can be seen in Figure 2 that the eastern part of Makassar City, especially the Tamangapa Landfill in Manggala District, is the area that most frequently experiences fires. The criteria for the distance to the air source based on the results of the water source area buffer can be seen that the Makassar urban area has a distance to the air source < 600 meters, so it is pretty capable in the event of a large enough fire.

Furthermore, for the criteria for building density, as shown in the Figure 2, it can be seen that when the building is in the north of Makassar City, which is an area that helps and includes the area, it can be vulnerable in the event of a fire. For fires, if analyzed with a buffer, several areas with distances exceeding <600 meters are obtained. Areas above the city limits include the southern part of Makassar City, which interacts with Takalar Regency, and the eastern part of Makassar City, located with Maros Regency. After the assessment is carried out for each day, it is continued by calculating the total value of each criterion on the grid as the SAW method by MacCrimmon (1968).

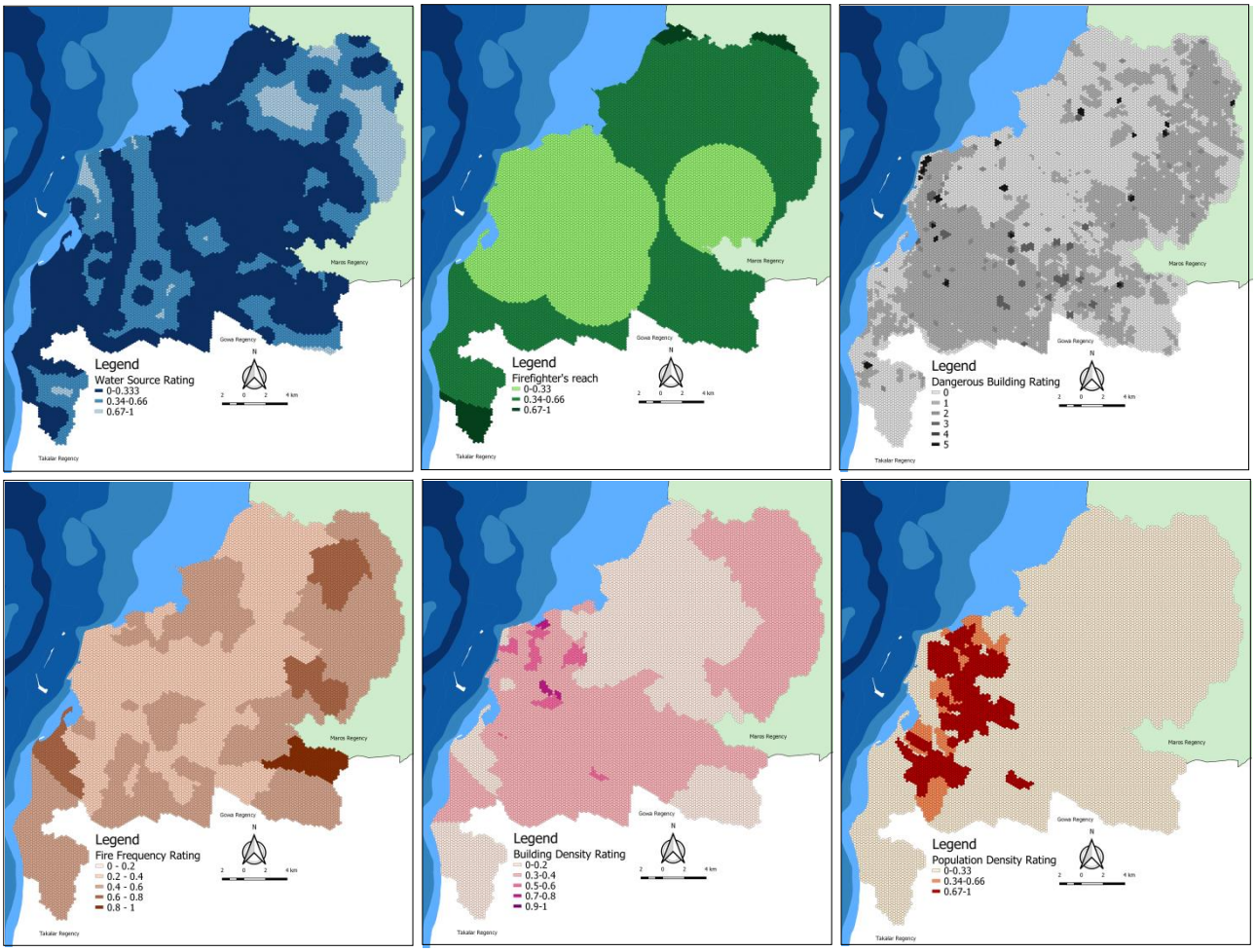

Figure 2. Results of Simple Weight Additive Analysis for Each Variable

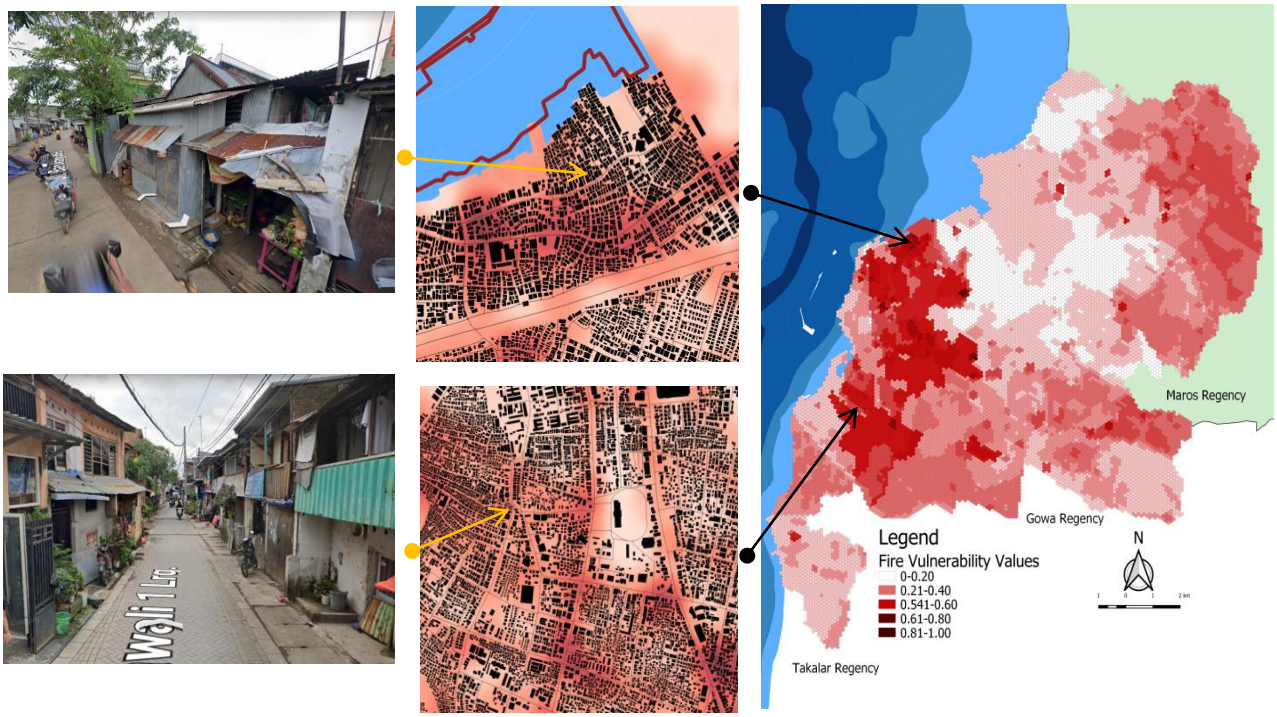

Figure 3. Map of Fire Hazards and Physical Condition of Fire Prone Areas in Makassar City

The analysis results show that the vulnerable areas tend to be in the northern and western parts of Makassar City. As shown in Figure 3(a), the northern part of Makassar City is located on Jl. Barukang Utara is a residential area with a dense population and buildings. In addition, this area has also experienced frequent fires before. The close distance between houses with a small road network will make it difficult for firefighters in the event of a fire. Many of the buildings in this area are semi-permanent houses. The materials used for building are flammable materials such as wood, plywood, and others, so they are more vulnerable in the event of a fire. In addition, there are no clear hydrants and evacuation routes in the event of a fire.

Furthermore, Figure 3(b) is located on Jl. Rajawali 1 Lr. 13B is a residential area with a high building density as well. In addition to the high building density, this area is densely populated with a relatively small road network width. The frequency of fires in this area is relatively low. This area is also quite close to the fire department because it is in an urban area. In addition, this area is also quite close to water sources. However, the density of buildings and residents makes this area prone to fires.

As shown in Figure 3, it can also be noted that the eastern part of Makassar City tends to be quite vulnerable. It is due to the density of buildings, the reach of firefighters, dangerous buildings, and the distance to water sources. Several points in the eastern part of Makassar City also have a relatively high frequency of fire occurrences.

4. CONCLUSIONS

Among the six fire susceptibility criteria, namely population density, building density, presence of dangerous buildings, distance to water sources, reach of firefighters, and frequency of previous fire events, the AHP results show that the importance of the criteria for densely populated areas is the greatest in the assessment of fire susceptibility. It reached a value of 0.29. The lowest criteria are the distance from the water source and the reach of the fire extinguisher, with a value of 0.06 each.

The fire vulnerability assessment results show that the northern and western parts of Makassar City are very prone to fires. It is caused by population density, building density, and the high frequency of fires. So, if viewed as a whole, fire mitigation should be deepened in the northern and western parts of Makassar City. As

a study note and suggestions for developing this assessment, the authors suggest further researchers consider the hazard and resilience factors in assessment indicators. In addition to reducing bias in the assessment, more complex data such as road width, the distance between buildings, and the level of community understanding of fire, temperature, and wind flow is recommended. The author also suggests conducting a time series assessment to see various fire vulnerability trends like fluid assessment and urban climate.

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